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FINAL REPORT

WINONA LAKE FEASIBILITY/DESIGN STUDY

Submitted To:

WINONA LAKE PRESERVATION ASSOCIATION
8 Fairlane Drive
Warsaw, Indiana 46580

INTERNATIONAL SCIENCE & TECHNOLOGY, INC.
10501 Hague Road
Fishers, Indiana 46038

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EXECUTIVE SUMMARY

International Science & Technology, Inc. (IS&T) has provided technical services to the Winona Lake Preservation Association in conducting a Feasibility/Design Study of Winona Lake, Kosciusko County, Indiana. The study was funded through the Indiana Department of Natural Resources Lake Enhancement Program (LEP). The combination Feasibility and Design Study is a result of an earlier study on Winona and several other area lakes in 1988. A conclusion of this study was that a dredging project should be undertaken to remove the large delta that has formed over the years at the mouth of Wyland Ditch.

The objectives of the Feasibility component of the study were three-fold:

- Assess the current condition of the lake and establish a baseline against which future changes can be measured.
- Identify potential threats to the well-being of the lake.
- Recommend lake and/or watershed management practices that minimize such threats.

To meet these objectives, four separate phases of the study were necessary. First, all relevant background information, including maps, previously collected water chemistry data, copies of correspondence, and biological data, were collected and reviewed. This information was critical to understand the current status of knowledge on the lake. Second, lake surveys were conducted to collect data on water quality, abundance of algae, bathymetry, and sediment chemistry. Third, a watershed survey was conducted. This involved compilation of land use information for development of a land use map of the entire watershed. In addition, the watershed survey involved the application of a computer model that resulted in identification of key problem areas in the watershed with respect to sediment and nutrient transport to the lake. The land use map and computer model results will be important tools for controlling and reducing the future influx of nutrients to Winona Lake. The survey also involved an analysis of bank stability in Wyland, Keefer-Evans, and Peterson Ditches. The fourth phase of the study involved the analysis of all data that had been collected, and development of recommendations that would have the greatest probability of improving the quality of this resource.

The primary objectives of the Design component of the project were to develop engineering plans and specifications for dredging the Wyland Ditch mouth, to develop erosion control measures, and to evaluate tributary bank stability. However, the feasibility of the dredging aspect of the project had not been fully evaluated prior to initiation of this study. Most importantly, a site for construction of a containment basin to dry the sediments had not been located. To accurately determine the size requirements for such a basin, a topographic and bathymetric survey of the area to be dredged was conducted. However, a thorough evaluation of two upland sites, as well as development of an in-lake plan, did not result in a solution that would allow the Design Study to proceed as originally proposed. Consequently, the conclusion reached was that dredging of the Wyland Ditch mouth is not feasible at this time.

Based on the findings of this study, a reduction in the quantity of sediment associated nutrients reaching the lake from the surrounding agricultural lands will be critical to slowing the rate of eutrophication of Winona Lake. Eutrophication is a term that describes the natural aging process of lakes, in which depth gradually decreases, vegetation encroaches, and the lake becomes marshy and nutrient rich. Eventually, lakes become swales and wooded areas. For most lakes, this process may take hundreds or even thousands of years, depending on the lake's physical characteristics and the degree of man's intervention in the process. In the case of Winona Lake, eutrophication has been accelerated due to the addition of excess nutrients (primarily nitrogen and phosphorus) in runoff from the watershed. A decrease in water clarity, absence of dissolved oxygen in the deeper waters, abundance of algae, and high nutrient concentrations near the lake bottom are all evidence of nutrient enrichment. Although in-lake restoration techniques could immediately improve conditions in the lake, application of best management practices (BMPs) at key problem areas will go farthest and be the most cost effective method for improving and maintaining water quality in the lake and tributaries.

The Winona Lake Preservation Association should pursue funding for watershed BMP implementation through the newest component of the Lake Enhancement Program, the Lake Watershed Treatment Program (LWTP). This program provides cost share assistance to land users for practices that reduce the amount of sediment associated nutrients entering a project lake. Application for assistance is made through the local Soil and Water Conservation District (SWCD) for a given project area, e.g., the Peterson Ditch watershed. The Lake Enhancement Program and the SWCD District Conservationist can provide further information on this program. Over the next few years, a volunteer monitoring program should be conducted to gage the effectiveness of upland controls and to determine whether additional measures are warranted.

In addition to BMPs that may be implemented through the LWTP, a project recently initiated by the SCS is also focusing on BMP application on watersheds within the northern Tippecanoe River drainage basin, which includes the Winona Lake watershed. This project is designed to accelerate BMP application through increased educational and technical assistance to land users.

A second major recommendation is that a Lake Enhancement Program Design Study be conducted on Peterson Ditch. The primary objective of this study would be to provide information for the design of stabilization measures in the lower reaches of this tributary. The results of the analysis of bank stability showed that the banks in this area of Peterson Ditch are unstable and are a current source of sediment to the lake. Wyland Ditch was comparatively stable and, despite periods of instability in the past, the ditch itself is not considered a major source of sediment at this time. Similarly, Keefer-Evans Ditch is in a relatively stable condition.

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SECTION 1. INTRODUCTION

This report represents the results of a Feasibility/Design Study conducted on Winona Lake by International Science & Technology, Inc. (IS&T) for the Winona Lake Preservation Association. The project was performed and funded under the provisions of the State of Indiana "T by 2000" Lake Enhancement Program (LEP). The LEP was established to ensure the continued viability of Indiana's public access lakes by controlling sediment related problems such as erosion and nutrient enrichment. The objectives of this program are to characterize the lake and surrounding watershed, identify water quality related problems, present alternative solutions, and recommend the most appropriate mitigation strategies for control of sedimentation and associated nutrient enrichment. The ultimate objective of the program is to restore the well being of the lakes through development of specific plans of action for restoration (Design Phase), and installation of the required control measure when appropriate (Construction Phase or Lake Watershed Land Treatment Program).

The combination Feasibility/Design Study was a result of earlier work on Winona Lake (Hippensteel, 1989) that identified a need for dredging of the Wyland Ditch inflow channel and mouth. One of the primary objectives of the Design component of the study was to provide bid ready documents and engineering plans for this, including the extent and depth of the area to be dredged, and plans for construction of sedimentation basins to dewater the dredge material. Development of recommendations for erosion control and evaluation of tributary bank stability were also objectives of the Design Study.

The Feasibility component of the project included collection of historical data on the lake, current water quality and biological data, land use analysis, and computer simulation of sediment and nutrient transport. Recommendations for management of the lake and watershed, including development of a long-term monitoring program, were also elements of the Feasibility Study.

1.1 WINONA LAKE

Winona Lake is located in Kosciusko County, adjacent to the town of Warsaw, Indiana and the community of Winona Lake (Figure 1). The lake has a surface area of 562 acres, a maximum depth of 80 feet, a mean depth of 30 feet and a retention time of 319 days (USEPA, Working Paper No. 348, 1976). The lake bottom consists primarily of sand, gravel, muck and marl (IDNR, 1988). The shores of the lake are heavily developed with single family residences and condominiums. The north shore of Winona Lake is dedicated primarily to municipal and industrial use. Data collected in 1980 documented 243 homes along the shores of Winona Lake (Hippensteel, 1989). Additionally, the Kosciusko County Fairgrounds is located on the north shore, and two swimming beaches are located on the east shore.

The Winona Lake watershed consists of 18,730 acres of agricultural, forested and urban land. The majority of the drainage enters the lake through three (3) tributaries: Wyland Ditch, Keefer-Evans Ditch

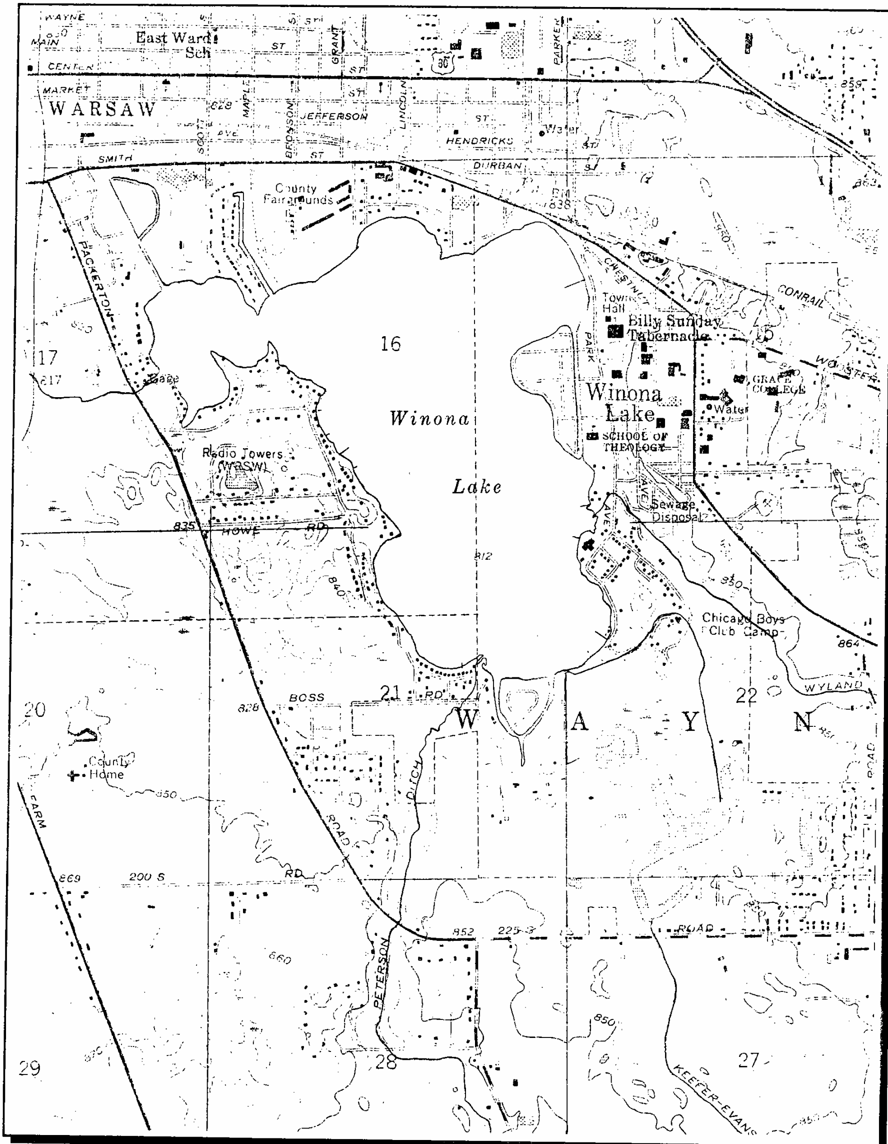

Figure 1. Portion of the Warsaw, Indiana quadrangle showing the location of Winona Lake.

and Peterson Ditch. Wyland Ditch enters Winona Lake on the east shore, south of the community of Winona Lake, and has a drainage area of 8,785 acres. Keefer-Evans Ditch has a drainage area of 2,919 acres and enters the lake on the southeast shore. Peterson Ditch enters Winona Lake on the southwest shore, and has a drainage area of 7,026 acres (Hippensteel, 1989). Winona Lake discharges into Eagle Creek, on the northwest shore, through a concrete dam with adjustable steel gates.

The acreage along the north shore of Winona Lake has and continues to be dedicated to municipal and industrial uses. The remaining acreage directly surrounding the lake has either been residential or oriented towards recreational uses. Aerial photography from 1965 depicts the entire shoreline of Winona Lake as being fully developed. A small wooded section of shore, near the inlet of Keefer-Evans Ditch, showed the least amount of development. Prior to 1965, a canal had been constructed on the east side of the lake connecting the northeast lobe with the main lake body. The canal runs in a north-south direction through the town of Winona Lake. Canals were also constructed along the northwest shore of the lake, immediately west of the fairgrounds. The canals appear to have been constructed in conjunction with residential development, providing lake access for home owners.

Geologically, the Winona Lake watershed is composed of Devonian age bedrock; largely limestone, dolomite and black shale. Unconsolidated deposits consist of sand and gravel outwash, and glacial till in hummocky moraine form. The glacially formed lake is the result of the advance and retreat of the Saginaw and Erie lobes of the main glacier that extended southwest from the Lake Erie and Saginaw Bay Basins during the most recent period of glaciation (14,000 to 22,000 years ago). The effect of this glaciation on north-central Indiana is evidenced by the moraine topography, with interspersed lakes, bogs, and glacial drainage troughs and plains (Clark, 1980).

Soils surrounding Winona Lake have been described by the Soil Conservation Service (SCS) as ranging from depressional to moderately sloping, and well drained to poorly drained. The two major soil associations found in this area are the Houghton-Palms and the Ormas-Kosciusko Associations.

The Houghton-Palms Association occurs in lands immediately surrounding the lake. This association is typically comprised of very poorly drained, mucky soils with level to depressional topography. The surface drainage pattern is poorly defined and ponding in low areas is common during wet periods. These soils are severely limited as sites for residential development, although large areas adjacent to lakes have been filled and developed for urban use.

The Ormas-Kosciusko Association predominates in the outlying lands surrounding Winona Lake. This association is characterized by sandy and loamy soils, and level to moderately sloping topography. The surface drainage pattern is also poorly defined, with water ponding in depressional areas during wet periods. The association is used primarily for cultivated crops, hay and pasture, and is well suited to residential development. The major soils in this association however, are limited as sites for septic tank absorption fields because of their poor filtering capacity.

1.2 NATURE OF THE PROBLEM

Sediment and nutrient loading have been identified as the predominant water quality impairments to Winona Lake. Prior to this study, the principal source of sediment loading was thought to be Wyland Ditch (Hippensteel, 1989). Sediment accumulation has been observed at the mouth of Wyland Ditch for over 50 years. Probable sources of recent sediment loading include the construction of a sewer line, completed in 1988, adjacent to Wyland Ditch, and construction of the Stonehenge Golf Course and associated residential development upstream. Lack of erosion control at these sites during construction was seen as a major contributor to sediment loading in Winona Lake (Hippensteel, 1989). Sediment accumulation at the mouth of Peterson Ditch has also been observed. An aerial photo taken during a precipitation event in spring 1989, showed an extensive sediment plume at the outlet of Peterson Ditch (Outdoor Indiana, May 1989).

In 1986, Winona Lake was placed in Trophic Class Three and given a Eutrophication Index (EI) value of 56 by the Indiana Department of Environmental Management (IDEM) as noted in the Indiana Lake Classification System and Management Plan (1986). This index value was based on data collected by the Indiana State Board of Health (ISBH) in 1976. A recent re-evaluation of this data gives the lake an EI value of 47 and changes the trophic Class of the lake to Class Two (Harold BonHomme, pers. comm., 1990). Lakes in Trophic Class Two are described by IDEM as intermediate quality, intermediate level eutrophic lakes which are often productive, but exhibit subtle trophic changes. Other characteristics include oxygen depletion below the thermocline during stratification, algal blooms during the summer months, and extensive macrophyte concentrations in the bays and littoral areas of the lake.

The original IDEM EI value placed Winona Lake in the Lake Management Group IV-D, as does the revised EI value of 47. Lakes in this group have the poorest water quality of any lakes in the state. Management priorities for Group IV-D lakes are to improve water quality as quickly as possible through restoration and nutrient abatement programs.

1.3 STUDY OBJECTIVES

The objectives of the overall study were twofold: (1) to complete a feasibility study, identifying potential threats to the water quality of Winona Lake and further defining impairments to the lake and watershed that were described in a preliminary investigation (Hippensteel, 1989); (2) to provide design specifications to remediate previously defined impairments in the Wyland Ditch watershed.

The objective of the feasibility component of the project was to fully assess the current conditions in the lake and watershed with respect to sedimentation and water quality. Based on this assessment, a plan for implementing appropriate mitigative strategies was developed. The mitigative techniques chosen were those having the greatest probability of success in improving the overall quality of the lake.

Four phases of activity were necessary to meet the project objectives. First, all relevant information pertaining to the lake and watershed (e.g., USGS topographic maps, aerial photographs of the lake and watershed, previous water quality and fisheries studies, and hydrologic, geologic and soil data) was collected and reviewed. This information was used to understand the physical setting of the lake, and the current status of knowledge regarding sedimentation and water quality problems.

The second phase of the study involved collection of field data. Water samples and in-situ chemical and physical data were collected from the lake and from the three tributaries to the lake. Sediment characteristics, algal community composition, and bathymetric data were also collected. These data provided the most recent evaluation of the chemical, biological and physical conditions in the lake.

A survey of the watershed was the third phase of the study. Areas of excessive nutrient and sediment loading were identified by using the Agricultural Non-Point Source Pollution (AGNPS) computer simulation developed by the U.S. Department of Agriculture. The watershed survey was critical in addressing problems at their source, and for developing the most appropriate mitigative strategies.

The final phase of this project was to develop recommendations to mitigate the problems observed in this study and in prior studies. The methods used in each phase of the project, and the results of the study are presented in the sections that follow.

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SECTION 2. HISTORICAL DATA

The following section describes the historical data collected for this study. This information included water quality studies, fishery and aquatic plant surveys, soils data, land use and hydrological data. Several state and county agencies as well as universities, were contacted in pursuit of this information. Table 1 presents a summary of historical data obtained for Winona Lake.

Table 1. Winona Lake historical data summary.

DATE	AGENCY	DESCRIPTION
1950	USGS	Lake Gage Curve
1968	Kosciusko Co. Health Dept.	Bacteriological Survey
1969	Kosciusko Co. Health Dept.	Bacteriological Survey
1970	IDNR	Fish Management Report
1973	U.S. EPA	National Eutrophication Survey
1976	ISBH	Lake Survey Data
1976	IDNR	Fish Management Report
1980	Kosciusko Co. Health Dept.	Bacteriological Survey
1982	IDNR	Fish Management Report
1985	Kosciusko Co. Health Dept.	Water Quality Survey
1985	ISBH	Environmental Emergency Incident Report
1987	IDEM	Fish Tissue, Sediment, and Water Quality Data
1987-1989	USGS	Lake Gage Height (in feet)
1988	IDEM	Correspondence
1988	IDNR	Report on Success of Walleye Stocking in Winona Lake
1988	Kosciusko Co. Health Dept.	Water Quality Survey
1989	Tri-State University	Highly Erodible Soils Maps
1989	Tri-State University	Preliminary Investigation of the Lakes of Kosciusko County
1989	SCS	Soil Survey of Kosciusko County

2.1 WATER QUALITY

Table 2 presents a summary of historical water quality data collected on Winona Lake. Sources of these

Table 2. Winona Lake historic water quality data.

DATE	SOURCE	TP (mg/L)	OP (mg/L)	NO_2+NO_3 (mg/L)	NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	CHLa (mg/m^3)	COND (umhos)	T.ALK (mg/L)	SURF. DO (mg/L)	SECCHI (ft)
8/70	IDNR	0.130			0.30					181	10.0	2.5
5/73	NES	0.027	0.009	1.440		0.110	0.800	4.20	500	203		4.5
8/73	NES	0.022	0.006	0.410		0.060	1.200	17.60	461	182		
10/73	NES	0.029	0.018	0.050		0.070	1.300	8.40	415	176		5.8
1975	Tri-State	0.130										3.5
7/76	ISBH	0.040	0.040	0.400		0.800					7.0	4.0
7/76	IDNR									137	9.0	4.0
6/82	IDNR									171	10.0	8.3
1985	Tri-State	0.030										
5/87	IDEM	0.030		1.400			0.910				9.4	6.5
8/88	Tri-State	0.030										6.5

data include the Indiana Department of Natural Resources (IDNR), U.S. EPA National Eutrophication Survey (NES), Indiana State Board of Health (ISBH), Indiana Department of Environmental Management (IDEM) and Tri-State University. Although there are inconsistencies among the parameters reported, nutrient concentrations have generally been low since 1976. The total phosphorus concentration in Winona Lake has remained near 0.03 mg/L. A secchi disk transparency of 8.3 feet was recorded by the IDNR in 1982. In both 1987 and 1988, secchi disk values of 6.5 feet were recorded by IDEM and Tri-State University, respectively.

Historic water quality data collected on the Winona Lake tributaries are presented in Table 3. The majority of the data were collected during the U.S. EPA National Eutrophication Survey in 1973 and 1974. Additional data sources include the Kosciusko County Health Department and Tri-State University. From the data presented it appears that, in general, nutrient input from these tributaries was not high. The data collected by Tri-State University in 1988, however, shows a marked increase in total phosphorus in each of the tributaries.

Winona Lake was selected to participate in the U.S. EPA National Eutrophication Survey (NES) in 1973. The NES was initiated in 1972 in response to a Federal administrative commitment to investigate the threat of accelerated eutrophication to freshwater lakes and reservoirs in the United States. The survey objectives were to develop information on nutrient sources, concentrations and their impacts on selected freshwater lakes. The information gathered was then used to formulate management practices relating to point-source discharge reduction and non-point source pollution abatement in the lake watersheds.

Twenty-seven (27) Indiana lakes were included in the 1973 NES Survey. Of these, Winona Lake was ranked sixteenth in overall trophic quality. The survey reported no known municipal or industrial waste-water treatment plants impacting the lake. It is known, however, that the town of Winona Lake discharged treated wastes to Winona Lake until February of 1972 when the wastes were diverted to the Warsaw treatment plant. Wastes from the Warsaw plant are discharged downstream from the lake outlet. At least four (4) storm sewers, at the time of the survey, discharged urban runoff to the lake. The NES report noted that one of these had received infrequent and unquantified spills of dairy wastes. The storm sewer draining the Kosciusko County fairgrounds was also noted. Nutrients from livestock waste could potentially reach Winona Lake, particularly during a rain event, via this storm sewer.

The NES reported that non-point sources contributed 99.2% of the phosphorus load to Winona Lake. Wyland Ditch contributed 46.8% of the non-point source phosphorus load, while Peterson Ditch contributed 36.3% and Keefer-Evans contributed 10.0%. The phosphorus export rates of these tributaries were somewhat higher than those of tributaries sampled elsewhere in Kosciusko County. All three tributaries flow through populated areas and may have been impacted by septic tank leachate to some degree.

The NES report concluded that the phosphorus loading to Winona Lake had been reduced as much as

Table 3. Historic water quality data for Winona Lake tributaries.

TRIBUTARY	DATE	SOURCE	TP (mg/L)	OP (mg/L)	NO_2+NO_3 (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	FLOW (CMS)
PETERSON DITCH								
	06/09/73	NES	0.105	0.042	1.920	0.110	2.000	0.595
	07/14/73	NES	0.020	0.009	0.500	0.075	2.000	0.074
	08/11/73	NES	0.030	0.009	0.420	0.370	1.600	0.051
	09/15/73	NES	0.100	0.054	0.399	0.072	1.200	0.028
	10/13/73	NES	0.080	0.016	0.590	0.084	1.200	0.054
	11/11/73	NES	0.025	0.008	0.294	0.016	0.450	0.045
	12/05/73	NES		0.012	0.260	0.076	0.900	0.244
	01/19/74	NES	0.240	0.028	3.500	0.086	1.500	0.543
	02/02/74	NES	0.075	0.025	3.100	0.050	0.800	0.736
	02/15/74	NES	0.060	0.015	1.680	0.095	1.500	0.340
	03/02/74	NES	0.045	0.015	2.080	0.015	1.000	0.481
	03/16/74	NES		0.015	1.760	0.045	1.700	0.680
	04/13/74	NES	0.035	0.015	1.180	0.025	1.500	0.538
	05/19/74	NES	0.060	0.020	1.500	0.070	1.400	0.651
	1988	Tri-State	0.140					
KEEFER-EVANS DITCH								
	06/09/73	NES	0.125	0.031	1.240	0.160	1.980	0.396
	07/14/73	NES	0.045	0.012	0.620	0.035	0.900	0.025
	08/11/73	NES	0.055	0.015	0.660	0.540	2.500	0.017
	09/15/73	NES	0.070	0.019	0.650	0.132	1.570	0.011
	10/13/73	NES	0.065	0.015	0.570	0.086	0.950	0.020
	11/11/73	NES	0.035	0.008	0.690	0.044	0.475	0.017
	01/19/74	NES	0.085	0.016	3.960	0.104	1.400	0.164
	02/02/74	NES	0.030	0.010	3.000	0.060	0.850	0.258
	02/15/74	NES	0.060	0.010	2.200	0.065	1.200	0.113
	03/02/74	NES	0.030	0.010	2.200	0.035	1.300	0.170
	03/16/74	NES	0.052	0.015	2.000	0.050	1.650	0.249
	04/13/74	NES	0.010	0.010	1.520	0.060	1.600	0.193
	05/19/74	NES	0.045	0.015	1.180	0.075	1.200	0.238
	05/18/85	Kos. Co.	0.040					
	1985	Tri-State	0.040					
	1988	Tri-State	0.140					

Table 3. Historic water quality data for Winona Lake tributaries (concluded).

TRIBUTARY	DATE	SOURCE	TP (mg/L)	OP (mg/L)	NO_2+NO_3 (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	FLOW (CMS)
WYLAND DITCH								
	06/09/73	NES	0.165	0.043	1.600	0.072	2.730	1.218
	07/14/73	NES	0.045	0.020	2.040	0.017	0.750	0.088
	08/11/73	NES	0.075	0.025	1.600	0.071	1.470	0.059
	09/15/73	NES	0.050	0.019	2.060	0.024	0.690	0.031
	10/13/73	NES	0.045	0.017	1.400	0.035	0.880	0.062
	11/11/73	NES	0.025	0.005	1.740	0.016	0.600	0.054
	12/05/73	NES	0.055	0.016	1.840	0.132	1.400	0.283
	01/19/74	NES	0.160	0.036	3.520	0.160	2.300	0.538
	02/02/74	NES	0.115	0.032	4.200	0.085	1.200	0.850
	02/15/74	NES	0.070	0.015	3.080	0.115	1.400	0.368
	03/02/74	NES	0.085	0.025	3.100	0.070	1.200	0.538
	03/16/74	NES	0.105	0.030	2.700	0.090	1.900	0.850
	04/13/74	NES	0.015	0.015	2.100	0.045	2.100	0.623
	05/19/74	NES	0.095	0.010	1.850	0.070	1.850	0.765
	05/18/85	Kos. Co.	0.050					
	1985	Tri-State	0.050					
	1988	Tri-State	0.140					

possible by the diversion of treated wastes from the town of Winona Lake to the Warsaw treatment plant. The study predicted that storm sewer phosphorus loads would prove to be insignificant, and that the lake would gradually improve in trophic condition once a new phosphorus equilibrium had been established.

The Kosciusko County Health Department conducted coliform surveys on Winona Lake in 1968, 1969, 1980, 1985 and 1988. In 1968, the county sampled 19 shoreline sites for coliform. Of these, 14 exhibited positive fecal coliform results, and all 19 sites tested positive for total coliform. However, a "positive" test only indicates the presence of bacteria, and is not necessarily cause for concern. The 1969 survey included 23 sites along the lakeshore. Fecal coliform were present in 18 of the 23 samples, with all sites having some level of total coliform growth. Ten (10) sites were sampled in 1980 and analyzed for fecal coliform only. Six of the these samples showed positive fecal coliform results. In May and July of 1985, Winona Lake was again sampled for fecal coliform only. Fecal coliform were present in 15 of the 18 sites sampled in May, and five (5) of the ten (10) sites sampled in July. The 1988 coliform survey analyzed 13 sites for total coliform only. Five (5) of the 13 sites exhibited positive total coliform results. The locations of samples with positive fecal coliform in 1985, and positive total coliform in 1988 are shown in Figure 2.

On 24 July 1985, the ISBH Environmental Emergency Response Team received notification of a substance of unknown origin floating approximately 400 yards downstream of a public swimming beach in Winona Lake. The substance was described as a black strip 100 yards long and 10-20 yards wide, and was

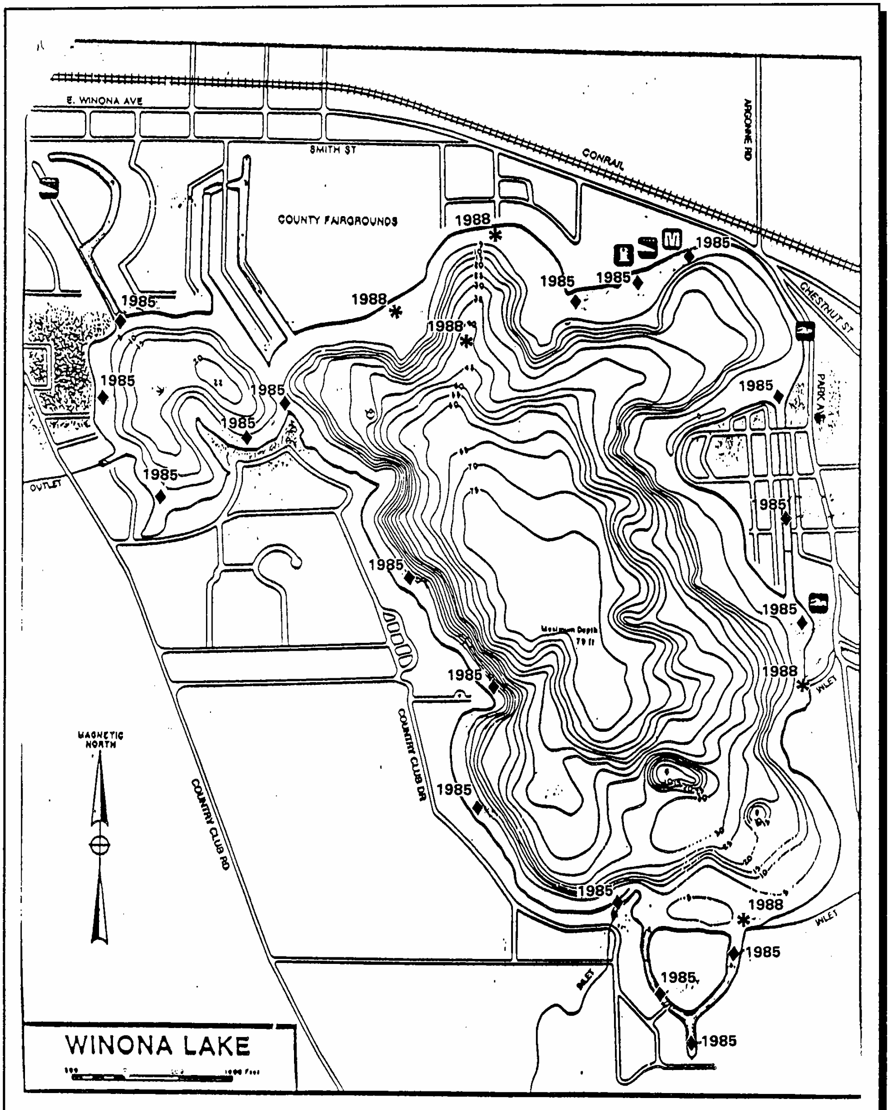

Figure 2. Winona Lake coliform sample locations - 1985 and 1988.

suspected to be of septic origin due to the associated strong sewage odor. As a precautionary measure, the beach was closed to the public until a thorough investigation could be conducted. Laboratory examination subsequently revealed that the coliform bacteria level of waters at the swimming beach had become sufficiently high to warrant continued closure of the beach. The contaminant was never specifically identified as being of septic origin, although elevated fecal coliform counts at the swimming beach indicated this. The origin of the spill was never identified. The contaminant was suspected, however, to have come from a local industry via an overflow tile discharging directly to the lake.

Priority pollutant analyses on sediment samples from the north shore of Winona Lake were conducted in 1987. The analyses revealed the presence of selected organic priority pollutants and metals, a number of which are not generally found in lake sediments (IDEM, 1988). Sources of these pollutants have not been confirmed, however IDEM identified the Gatke dump and the Dalton Foundry as potential sources. IDEM has conducted further testing of runoff from these industries, and is currently working closely with both Gatke and Dalton to reduce inputs of organics to Winona Lake.

In addition to the sediment and water quality data, analysis of fish tissues was also conducted by IDEM in 1987. All samples were below the established levels for human consumption, and no advisories or limitations were imposed based on the sample results.

2.2 FISH POPULATION SURVEYS

Fish population surveys of Winona Lake were conducted in 1970, 1976 and 1982 by IDNR. Species documented in these survey reports and their relative abundance are listed in Table 4. Included in these survey reports are selected water quality measurements and a list of common species of aquatic plants found in the lake at the time of the survey.

The 1970 fishery survey found that Winona Lake supported a warm-water fishery dominated by gizzard shad (Dorosoma cepedianum). A substantial bluegill population (Lepomis macrochirus) and a fair largemouth bass population (Micropterus salmoides) existed in the lake, but on the whole, the survey found the fishery to be undesirable. The report recommended that the fisheries remain unaltered, however, to determine if largemouth bass and bluegill could naturally become the dominant species.

The 1976 fishery survey found a more satisfactory population of yellow perch (Perca flavescens), bluegill, largemouth bass and channel catfish (Ictalurus punctatus). The dominant species collected, however, was gizzard shad. To increase predation on forage species, such as gizzard shad, the report recommended stocking walleye (Stizostedion vitreum) fingerlings. The eutrophication of Winona Lake was also mentioned as an impediment to developing a more satisfactory sport fishery. Hypolimnetic oxygen depletion is noted as being common during the summer months, reducing the "living-space" for fish. The report recommended increasing this living space by means of artificial aeration and restricting vegetation control, but noted that the high cost of aeration and public opposition to weed control restrictions would

Table 4. Fish species and relative abundance in Winona Lake. (IDNR Fish Management Reports)

COMMON NAME	SCIENTIFIC NAME	1970	1976	1982
Gizzard Shad	Dorosoma cepedianum	45.4%	28.2%	1.8%
Bluegill	Lepomis macrochirus	18.6%	15.7%	7.5%
Spotted Sucker	Minytrema melanops	5.6%	3.6%	3.3%
Largemouth Bass	Micropterus salmoides	5.4%	4.8%	2.0%
White Sucker	Catostomus commersoni	4.3%	3.2%	3.6%
White Bass	Morone chrysops	3.0%	2.0%	1.8%
Channel Catfish	Ictalurus punctatus	2.8%	3.8%	5.4%
Pumpkinseed	Lepomis gibbosus	2.2%	0.9%	**
Quillback	Carpiodes cyprinus	2.0%	0.5%	**
Spotted Gar	Lepisosteus oculatus	1.9%	0.1%	0.6%
Black Crappie	Pomoxis nigromaculatus	1.9%	0.5%	4.8%
Carp	Cyprinus carpio	1.7%	1.3%	1.9%
Yellow Bullhead	Ictalurus natalis	1.5%	0.3%	0.4%
Longear Sunfish	Lepomis megalotis	1.3%	5.6%	**
White Crappie	Pomoxis annularis	1.1%	0.1%	**
Yellow Perch	Perca flavescens	0.6%	24.0%	61.3%
Northern Hogsucker	Hypentelium nigricans	0.4%	**	**
Warmouth	Lepomis gulosus	0.2%	0.5%	0.3%
Golden Redhorse	Moxostoma erythrurum	0.2%	**	< 0.1%
Brook Silverside	Labidesthes sicculus	numerous	observed	observed
Spotfin Shiner	Notropis spiloterus	numerous	0.8%	**
Logperch	Percina caprodes	**	1.1%	observed
Longnose Gar	Lepisosteus esseus	**	0.8%	0.4%
Rock Bass	Ambloplites rupestris	**	0.8%	0.7%
Northern Pike	Esox lucius	**	0.4%	0.4%
Brown Bullhead	Ictalurus nebulosus	**	0.4%	2.6%
Redear Sunfish	Lepomis microlophus	**	0.3%	< 0.1%
Lake Chubsucker	Erimyzon sucetta	**	0.2%	**
Green Sunfish	Lepomis cyanellus	**	0.2%	< 0.1%
Black Bullhead	Ictalurus melas	**	0.1%	0.7%
Golden Shiner	Notemigonus crysoleucas	**	0.1%	< 0.1%
Bluntnose Minnow	Pimephales notatus	**	0.1%	**
Bowfin	Amia calva	**	**	< 0.1%
Fathead Minnow	Pimephales promelas	**	**	< 0.1%
Johnny Darter	Etheostoma nigrum	**	**	observed

** not observed

make these management techniques impractical.

The fishery survey conducted in 1982 found a large and varied sport fish population dominated by yellow perch. The survey report noted that growth and condition of bluegill, channel catfish and black crappie (Pomoxis nigromaculatus) were good, but limited by the lack of aquatic vegetation. The lake was once again recommended for walleye stocking. The walleye would serve to keep the populations of yellow perch, gizzard shad and other forage species in check. Additionally, ideal walleye spawning habitat (extensive sand and gravel areas open to wind and wave action) exists in Winona Lake.

In April and May of 1986, and again in June of 1987, Winona Lake was stocked with walleye. A survey and report documenting the success of these stockings was completed in 1987. The report concluded that walleye survival in Winona Lake was excellent, and recommended an additional stocking for 1988.

2.3 AQUATIC PLANT SURVEY

Aquatic plant surveys conducted by the IDNR during the fishery surveys of 1970, 1976 and 1982 identified thirteen (13) plant species in Winona Lake. These species are presented in Table 5.

Table 5. Historic data on aquatic plant species found in Winona Lake. (IDNR Fish Management Reports)

COMMON NAME	SCIENTIFIC NAME	1970	1976	1982
Water Lily	Nymphaea spp.	X	X	
Spatterdock	Nuphar advena	X	X	X
Spikerush	Eleocharis spp.	X		
Cattail	Typha spp.	X	X	
Sago Pondweed	Potamogeton pectinatus	X		
Milfoil	Myriophyllum spp.	X		
Chara	Chara spp.	X	X	
Filamentous algae		X	X	X
Coontail	Ceratophyllum demersum		X	
Curly-leaf Pondweed	Potamogeton crispus		X	X
Leafy Pondweed	Potamogeton foliosus		X	
Bulrush	Scirpus spp.		X	X
Slender najas	Najas spp.			X
Pithophora				X

Due to the extensive growth of aquatic vegetation in previous years, chemical vegetation control was a recommendation of the 1970 survey report. Comments recorded in subsequent reports made note of the lack of aquatic vegetation, and attributed this to the annual use of herbicides in most areas of the lake.

2.4 ERODIBLE SOILS

Areas of highly erodible soils in the Winona Lake watershed were identified from reports published by the Kosciusko County Soil and Watershed Conservation Districts. These reports, produced in cooperation with the SCS and other agencies, identify areas with high proportions of sheet, rill and gully erosion.

An additional source of information was a map of erodible soils in Kosciusko County prepared by Dr. Peter Hippensteel (Tri-State University, Angola, IN).

2.5 LAND USE

Historically, the majority of the land in Kosciusko County has been utilized for agriculture, with grain farming and livestock production the major farming activities. According to a 1941 land use report for the county, the main crops grown were corn, soybeans and wheat. Data obtained from the Conservation Technology Information Center (CTIC) for 1984 and 1988 showed the majority of the crop land to be used for corn production, followed by soybeans and small grain crops (such as wheat, rye, barley, oats, etc.). In 1984, conservation tillage practices were utilized on 45 percent of the active cropland. The primary type of conservation tillage practiced in 1984 was mulch-till, where the total soil surface is disturbed just prior to planting and weed control is accomplished using a combination of herbicides and/or cultivation. At least 30 percent of the soil surface is left covered by residue after planting to reduce soil erosion by water and wind. CTIC data for 1988 indicate conservation tillage to be practiced on 49 percent of the active cropland in Kosciusko County. Once again, mulch-till was the primary type of conservation tillage, with no-till accounting for 10 percent of the conservation tillage practiced. No-till conservation tillage leaves the soil undisturbed prior to planting. Planting is done in a narrow seedbed created by a planter or drill and weed control is accomplished using herbicides.

2.6 SIGNIFICANT NATURAL AREAS AND ENDANGERED OR THREATENED SPECIES

Significant natural areas and endangered and threatened species in the Winona Lake watershed were identified by the IDNR Division of Nature Preserves. The Division of Nature Preserves has a database of information pertaining to these significant areas and species and can identify locations of their occurrence by USGS quadrangle map, giving latitude and longitude coordinates. Table 6 contains a listing of these species and areas as identified by quadrangle.

Table 6. Significant natural areas and endangered/threatened species in the Winona Lake watershed.

USGS QUADRANGLE	SPECIES COMMON NAME	SPECIES SCIENTIFIC NAME	STATUS	LAT.	LONG.
Warsaw					
Arethusa Bog Natural Area					
	Forested Fen	Wetland - Fen Forested		410925	854747
	Bog Rosemary	Andromeda glaucophylla	ST	410925	854747
	Swamp-Pink	Arethusa bulbosa	SE	410925	854747
	Softleaf Sedge	Carex disperma	SE	410925	854747
	Large Whorled Pogonia	Isotria verticillata	WL	410925	854747
	Mountain Holly	Nemopanthus mucronatus	SR	410925	854747
	Small Green Woodland Orchis	Platanthera clavellata	SR	410925	854747
Stafford Lake Natural Area					
	Circumneutral Bog	Wetland - Bog Circumneutral		411015	854650
Winona Lake					
	Nuttal Bushclover	Lespedeza X Nuttalli #	SR	411237	854945
	Least Bittern	Ixobrychus exilis #	SSC	411250	854940
	Small Purple-Fringe Orchis	Platanthera psycodes #	SR	411250	854940
	Least Weasel	Mustela nivalis #	SSC	411303	854905
	Kirtland's Snake	Clonophis kirtlandii #	ST	411320	854919
	Blanding's Turtle	Emydoidea blandingii #	SSC	411325	854945
	Eastern Massasauga	Sistrurus catenatus catenatus #	ST	411325	854945
	Whorled Water-Milfoil	Myriophyllum verticillatum #	ST	411325	854945
	Fries Pondweed	Potamogeton friesii	SE	411325	854945
	Redheadgrass	Potamogeton richardsonii	SE	411325	854945
	Horned Pondweed	Zannichellia palustris	SE	411325	854945
	Rayed Bean	Villosa fabalis #	SSC	411350	855010

There were no significant natural areas or endangered/threatened species located in the North Manchester North, Pierceton and South Whitley West quadrangles.

Status: SE = endangered; ST = threatened; SR = rare; SCC = special concern; WL = watch list; # = observed prior to 1960

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SECTION 3. METHODS

This section of the report describes the methods used to complete the Feasibility component of this project. The data collection efforts for this project were divided into two sub-tasks: (1) a lake survey, and (2) a watershed survey. These subtasks are described below.

3.1 LAKE SURVEY

IS&T personnel conducted a survey of Winona Lake during the late summer and fall of 1989 to collect the information required for a detailed assessment of the physical, chemical and biological conditions in the lake and watershed. Samples were collected to analyze lake and tributary water quality, phytoplankton species and abundance, and sediment composition. A bathymetric survey of the tributary mouths and surrounding area was also conducted. The methods used for sample collection and other components of the field survey are described below.

3.1.1 In-situ Measurements

In-situ water quality, water samples and phytoplankton were collected on 24 August 1989 at one (1) in-lake station located at the deepest part of the reservoir (Figure 3). In-situ profile measurements of temperature, dissolved oxygen and pH were made using a Hydrolab "Surveyor II" Environmental Data System. Measurements were recorded at the surface, three feet, five feet, at five foot intervals through the thermocline, and at ten foot intervals to the lake bottom. Secchi disk transparency was measured on the shaded side of the boat. The Secchi disk was lowered until it disappeared, and then raised until it reappeared. The average of these two depths was reported as the Secchi disk depth. Percent light transmission was recorded at three feet using a Martek Model XMS transmissometer. This instrument was calibrated on the lake prior to use.

3.1.2 Chemical Measurements

Water samples were collected at the surface, mid-depth (40 feet) and 55 feet using a 6-L (6.6 quart) vertical Van Dorn water sampler. The bottom sample from the water column should have been collected at a depth of 79 feet, but was not due to sampling apparatus constraints. All in-lake water samples were collected at the same location as the in-situ data. Samples for nutrient analysis were poured directly from the Van Dorn into clean 4-L Cubitainer containers. Aliquots for fecal coliform analysis were poured into sterilized 100 ml Whirlpak containers. Separate aliquots were also collected for chlorophyll a analysis. All samples were immediately placed in coolers and stored at 4°C prior to shipment to the IS&T analytical laboratory. Analyses were begun within 24 hours of collection. Table 7 lists the analytes measured in the water samples and the methods used to conduct the analyses.

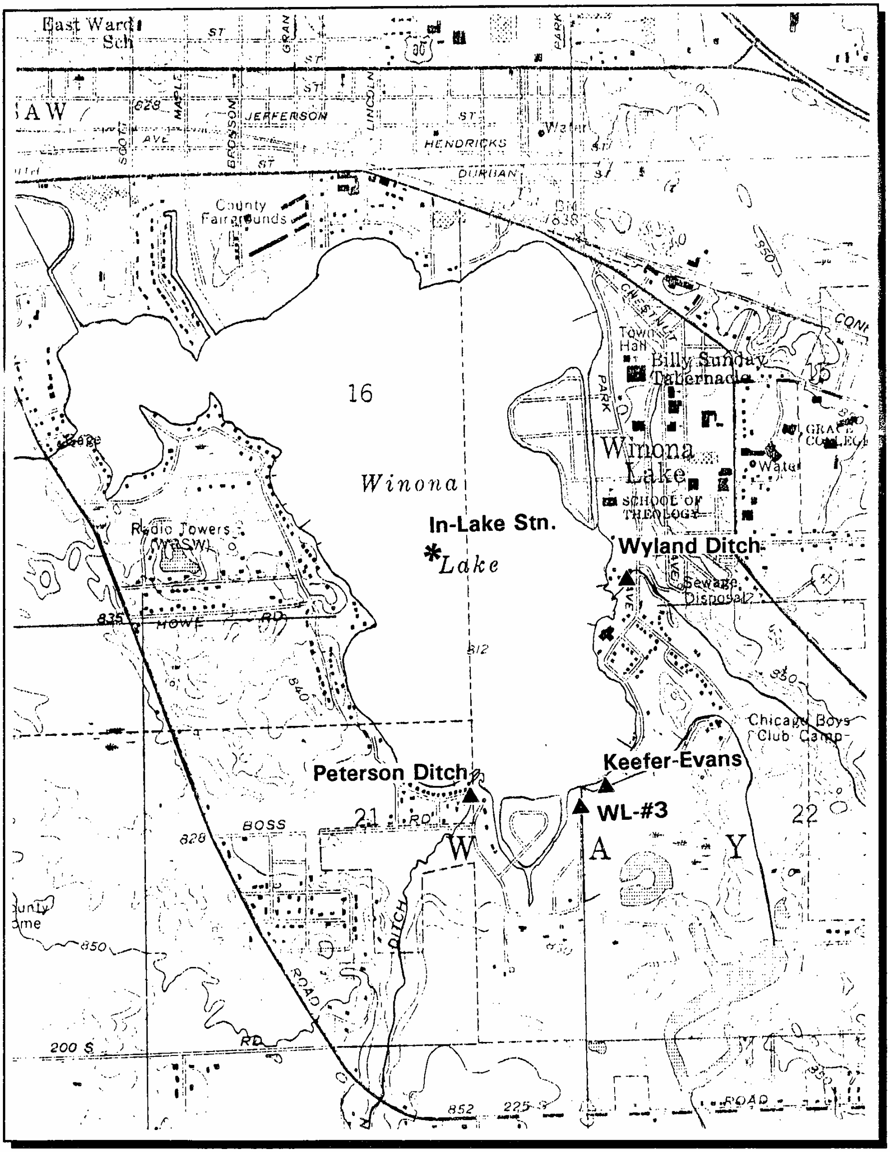

Figure 3. In-lake and tributary sampling locations.

Table 7. Chemical parameters and analytical methods used in evaluating Winona Lake water samples.

PARAMETER	INSTRUMENT OR METHOD	REFERENCE
Chlorophyll a (Chla)	Spectrophotometer	Standard Methods, 16th ed.
Fecal Coliform	Incubation, visual count	Standard Methods, 16th ed.
Ammonia ($N-NH_4$)	Flow Injection Analysis	EPA 350.1
Nitrate (NO_3)	Flow Injection Analysis	EPA 383.2
Total Kjeldahl Nitrogen (TKN)	Flow Injection Analysis	EPA 351.2
Ortho Phosphorus (OP)	Flow Injection Analysis	EPA 365.1
Total Phosphorus (TP)	Flow Injection Analysis	EPA 365.1
Total Suspended Solids (TSS)	Gravimetric	EPA 160.2
Temperature	In-situ Hydrolab Surveyor II	
Dissolved Oxygen (DO)	In-situ Hydrolab Surveyor II	
pH	In-situ Hydrolab Surveyor II	

In addition to the water samples, quality assurance samples were also collected in the field and included in the shipment to the analytical laboratory. These samples consisted of a blank (deionized water that was poured into the Van Dorn and then into a Cubitainer) and a duplicate sample. The blank sample was used to evaluate potential contamination due to field procedures (e.g., nutrient or bacteria residues in the sampler or in the sample containers). The duplicate sample, obtained from a second water sample collection at one of the three (3) depths, provided a measure of variability within the water column.

Water quality samples were also collected from the three tributaries under baseflow and storm event conditions. Baseflow samples were collected on 29 August 1989, and storm event samples were collected on 15 November 1989. The locations of these sample sites are shown in Figure 3. One grab sample was collected from each tributary, per event, by immersing a clean, rinsed and labeled 1-L Cubitainer into the stream at mid-channel. The samples from each event were placed on ice and shipped to the IS&T analytical laboratory within 24 hours of collection. Samples were analyzed for all the parameters listed in Table 7, with the exception of fecal coliform.

3.1.3 Biological Sample Collection

Two vertical plankton tows were taken using an 80μ mesh plankton net with an opening of one foot. The tows were taken from the same in-lake sampling station as the in-situ and chemical measurements. The first tow was from a depth of five (5) feet to the surface. The second was from a depth of 20 feet and included the thermocline. The plankton samples were immediately preserved with Lugol's solution and stored in labeled, opaque bottles. Phytoplankton were identified to species and enumerated using the settling chamber-inverted microscope technique described by H. Utermöhl (Sournia, 1972).

3.1.4 Sediment Sample Collection

A sediment survey was conducted in the lake and in each of the three tributaries to the lake. Sediment samples were collected from each tributary along a transect running from a point 100 feet upstream from the tributary mouth to a point in the lake 100 feet downstream from the mouth, and along a second transect encompassing the width of the shoal. A total of seven (7) samples were collected from each tributary area. An example of the transects and sample numbers assigned to each location are shown in Figure 4. The samples were spaced approximately 50 feet apart, with the exception of Keefer-Evans Ditch. Due to the small size of the delta at Keefer-Evans Ditch, samples #3 through #7 are spaced 30 feet apart. The hard bottom prevented the use of the sediment core sampler, therefore a Petite Ponar dredge was utilized to obtain the sediment samples. These samples were immediately placed in 250 ml containers and shipped in coolers via overnight courier to the IS&T laboratory. The top three (3) inches of sediment were analyzed for TP and TKN. Additionally, particle size analyses were conducted on samples from Wyland Ditch to assess the likelihood of sediment resuspension.

As a second component of the sediment survey, sediment probings were conducted at each sediment sampling station. A sediment probe was used to detect the depth to the sediment surface and to detect the probe refusal depth, or the depth to which the probe may be pushed into the sediments without meeting resistance. This information was then used to provide an indication of the depth of recently deposited sediment.

3.1.5 Bathymetric Survey

Using electronic surveying equipment, a bathymetric survey was conducted at the mouth of each tributary to Winona Lake. Survey points were chosen so as to include the entire shoal area of each tributary, and to fully characterize the bottom contours of the lake. A Digital Electronic Measuring device (DEM) was used to obtain elevations of the lake bottom at the survey points. All elevation measurements were tied

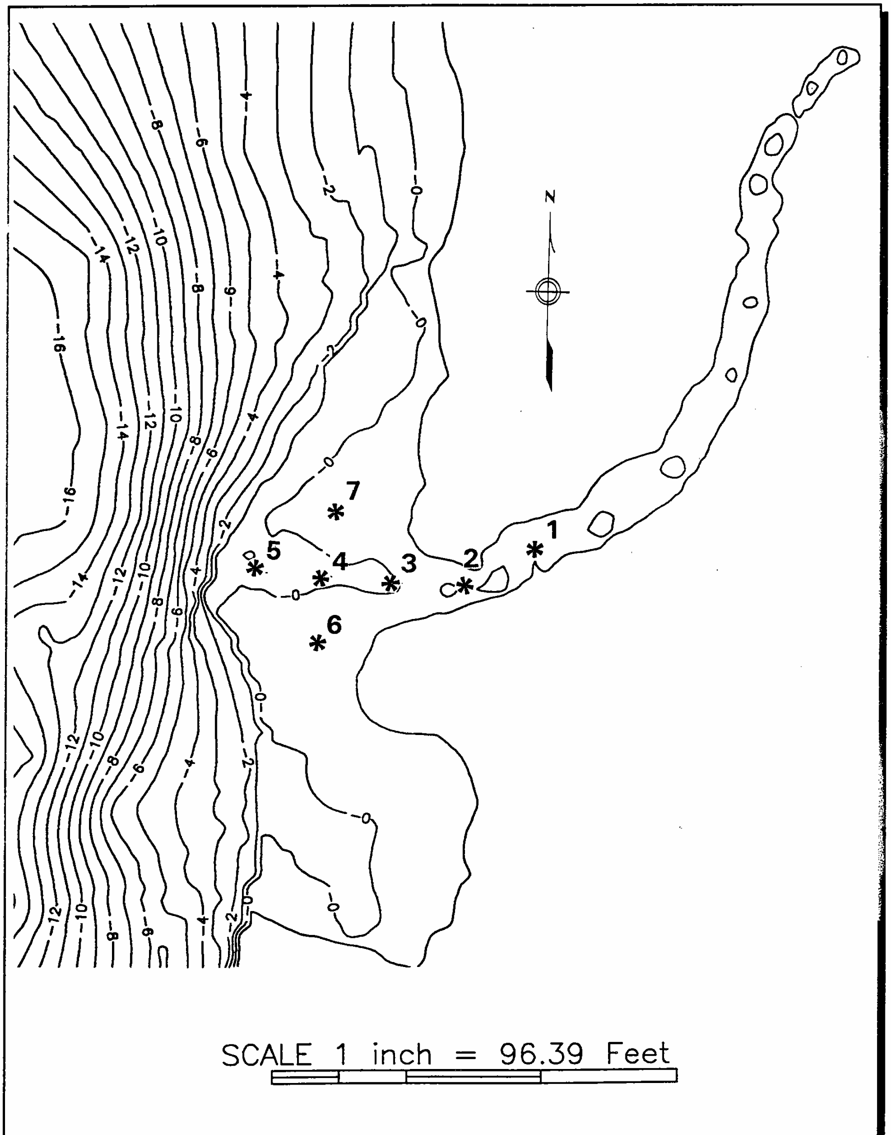

Figure 4. Sediment survey transect and sample numbers used for each sediment survey location.

into a USGS benchmark. A contour mapping software package ("SURFER") was used to develop contour maps of each surveyed area from elevations and coordinate data.

An estimate of the amount of sediment deposition at the mouth of Wyland Ditch was made by comparing a 1965 hydrographic survey (IDNR, 1965) with the 1989 IS&T survey. The volume of water contained in the Wyland Ditch tributary region was determined using the following equation (Wetzel and Likens, 1979):

$$V=\frac{h}{3}\left(A_1+A_2+\sqrt{A_1 A_2}\right)$$

where:
V = volume
h = depth of stratum
A_1 = area of upper surface
A_2 = area of lower surface

Estimates of changes in lake sediment accumulation were obtained by comparing the volume of water within the area surveyed in 1989 with the volume in the same area of the 1965 survey. The 1989 data were corrected for the lake level at which the 1965 survey was referenced.

3.2 WATERSHED SURVEY

Characterization of the current conditions in the Winona Lake watershed was oriented toward identifying the principal sources of sediment and nutrient loading. Components of this survey included:

- Hydrologic characterization
- Land use delineation
- Erodible soil evaluation
- Sediment/nutrient modeling

3.2.1 Hydrological Data

The principal hydrologic parameter of interest in developing a restoration strategy for Winona Lake is the hydraulic retention time. This is defined as the length of time required for the entire volume of the lake to be replaced with "new" water from runoff and direct precipitation. The information used in calculating the residence time included the lake volume, average annual runoff for the Winona Lake watershed, annual rainfall, and evaporation from the surface of the lake.

3.2.2 Stream Channel Characterization

An evaluation of the three major influent streams: Wyland Ditch, Keefer-Evans Ditch, and Peterson Ditch, was conducted in November 1989. The purpose of this evaluation was to analyze stream bank stability and classify the stream channel reaches according to the major variables that control channel geomorphology. The three stream systems were classified using a system developed by David L. Rosgen, U.S. Forest Service (Rosgen, 1986). The Rosgen Stream Classification System categorizes stream channels according to gradient, sinuosity, width/depth ratio, dominant size of channel materials, valley confinement, and landform features including dominant soils and stability.

The physical features that form the basis of the Rosgen system also provide valuable information on habitat suitability. For each stream classification in the Rosgen system, specific measures have been developed to restore and/or improve fish habitat. The system is also important for predicting the response of a stream channel to altered flow regimes, or changes in sediment supply. Depending on the stream's classification, a reduction in external sediment loading, such as that which would occur if best management practices were implemented, may or may not result in reduction of in-stream sediment transport. For some streams, the process of recovery from excess sediment supply may take many years, and the stream could continue to supply sediment from the banks themselves long after upland sources have been controlled. For these streams, measures to stabilize the channel and restore the natural pattern of the stream may be necessary in conjunction with upland sediment controls.

For Wyland Ditch, separate classifications were developed for the stream upstream of CR 450 South, and for the section from Winona Lake to CR 450 South. Two classifications were also given to Peterson Ditch; one based on channel characteristics just upstream of Winona Lake, and the other for the area near Country Club road. Keefer-Evans Ditch was given a single classification.

3.2.3 Land Use Delineation

Major land use patterns in the Winona Lake watershed were identified using recent (1985) aerial photographs (1:2000 scale) of the lake and watershed, USGS topographic maps (1:24,000 scale), and site reconnaissance. Several steps were necessary to develop the final land use map of the entire watershed.

First, the watershed boundary was outlined on topographic maps and digitized into IBM-PC compatible data files along with key geographical features (e.g., lake shorelines, streams, roads and towns). Land use within the watershed was delineated using aerial photographs, and assigned to one of sixteen (16) unique land use categories (Table 8). The border of each land use type was then digitized into IBM-PC compatible data files. These files were overlain onto the watershed boundary and geographical feature data files. Coverage maps and tabular summaries of land use in the watershed, as well as the data files to produce them, were developed using IS&T proprietary software. The results of this task were used as input parameters for modeling sediment and nutrient loading to the watershed (Section 3.2.4).

Table 8. Land use categories designated in the watershed survey.

1. Water Surface
2. Wetlands (including approximate stream corridors)
3. Forest (tree groups larger than 0.25 acre)
4. Open Land/Vacant Lots (no structures or livestock)
5. Pasture (grazed lands)
6. Row Crops (corn, beans, etc.)
7. Non-row Crops (wheat, hay, etc.)
8. Orchard
9. Feedlot
10. Low Density Residential/Rural (1 dwelling/acre)
11. Medium Density Residential (2-5 dwellings/acre)
12. High Density Residential (6 or more dwellings/acre)
13. Commercial/Industrial (industrial parks, malls)
14. Institutional (schools, parks, golf courses)
15. Bare/Unseeded Ground (construction sites)
16. Resource Extraction (borrow pits, timber sites)

3.2.4 Erodible Soils Evaluation

The Kosciusko County Soil and Water Conservation District (SWCD) has prepared a detailed analysis of soil erodibility in this county. Additionally, Dr. Peter Hippensteel (Tri-State University, Angola) has identified specific areas of highly erodible soils within the Winona Lake drainage basin. These studies were the primary sources of information used in characterizing the extent of erodible soils within the watershed.

3.2.5 Sediment/Nutrient Modeling

Information on land use, climate, soils and hydrology were combined to provide input parameters for use in the Agricultural Non-Point Source Pollution Model (AGNPS), a system developed by the U.S. Department of Agriculture-Agricultural Research Service in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service. The PC-based model was designed to simulate the sediment and nutrient contributions from watersheds under predefined hydrologic conditions. AGNPS operates on a grid basis and requires that the watershed be divided into a series of discrete squares, or cells. Twenty-two input parameters, covering a wide range of physical and chemical characteristics are assigned to each cell (Table 9). Sediment and nutrients are routed through the watershed; their concentrations in each cell being a function of upstream loading and the unique cell attributes, which can either increase or diminish the non-point pollution load. Sediment, nutrient, and hydrologic characteristics may be summarized for any cell along the flow path and at the watershed outlet. The model also allows the user to highlight cells with specific characteristics, such as high sediment phosphorus. In addition,

Table 9. Input parameters used in the AGNPS model[1].

TITLE	DESCRIPTION
Cell Number	ID number of current cell
Receiving Cell	ID of cell receiving outflow from current cell
SCS Curve Number	Relates runoff mass to rainfall mass (inches)
Field Slope	Mean slope of fields (%)
Slope Shape	Indicates concave, convex or uniform slope shape
Slope Length	Indicates average field slope length (feet)
Channel Slope	Mean slope of stream channel (%)
Side Slope	Mean slope of stream channel banks (%)
Roughness	Manning's Roughness Coefficient for channels
Soil Erodibility	K-Factor from Universal Soil Loss Equation
Crop Practice	C-Factor from Universal Soil Loss Equation
Conservation Practice	P-Factor from Universal Soil Loss Equation
Surface Condition	Indicates degree of land surface disruption
Aspect	Principal drainage direction
Soil Texture	Indicates sand, silt, clay or peat
Fertilization	Indicates level of added fertilizer
Incorporation	Indicates % fertilizer left on soil after storm
Point Source Flag	Indicates presence/magnitude of any point source
Gully Source	Override estimate of gully erosion magnitude
COD	Level of chemical oxygen demand generated
Impoundment Flag	Indicates presence/absence of terrace systems
Channel Flag	Indicates presence/absence of defined streams

[1] Parameters represent estimated conditions within each cell.

land use and other characteristics may be hypothetically altered to determine the effect of future changes on sediment and nutrient loading. The model provides estimates for single precipitation events only, so the user must define a "design storm" for the analysis.

Based on recommendations of AGNPS developers, the Winona Lake watershed was divided into a series of 40-acre cells. Each cell was characterized according to the parameters listed in Table 9. The design storm chosen was a two year, 24-hour event. This is defined as the largest storm that can be expected to occur once every two years, based on a 30 year period of record. For Winona Lake, this was a 2.7 inch rainfall (U.S. Department of Commerce, 1966). Nutrient, sediment and runoff maps were produced using the AGNPS Graphical Interface System.

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SECTION 4. RESULTS AND DISCUSSION

4.1 LAKE SURVEY

This investigation included in-situ, chemical and biological water quality measurements; sediment analyses; and bathymetric mapping. These data were used to summarize conditions in the lake and assess its current trophic status.

4.1.1 In-situ Measurements

In-situ water quality measurements are presented in Figure 5 and Table 10. These data indicate that

Table 10. Winona Lake in-situ water quality measurements. (24 August 1989)

DEPTH (ft.)	TEMP (C)	DO (mg/L)	pH	% TRANS. @3 ft.	SECCHI DISK (ft)
0.0	23.8	10.75	8.4		4.27
3.0	23.8	10.65	8.5	36.1	
5.0	23.9	10.59	8.5		
10.0	23.9	10.45	8.5		
15.0	23.2	8.30	8.3		
20.0	21.1	0.71	7.7		
25.0	15.6	0.07	7.6		
30.0	11.9	0.08	7.7		
40.0	9.8	0.05	7.7		
50.0	8.9	0.05	7.7		
60.0	8.5	0.05	7.7		
70.0	8.3	0.05	7.7		
80.0	8.2	0.05	7.7		

Winona Lake was thermally stratified at the time of sampling, with the thermocline occurring between 20 and 30 feet.

Dissolved oxygen (DO) concentrations were between 10.75 and 8.30 mg/L from the surface to a depth of 15 feet. The first five readings, from the surface through ten (10) feet were supersaturated, while the oxygen concentration at 15 feet, (i.e., 8.30 mg/L) was 99% saturated. The oxygen concentrations dropped sharply from 15 to 20 feet, with anoxic conditions from this depth to the lake bottom. The clinograde DO profile (Figure 5) is generally indicative of productive, eutrophic lakes.

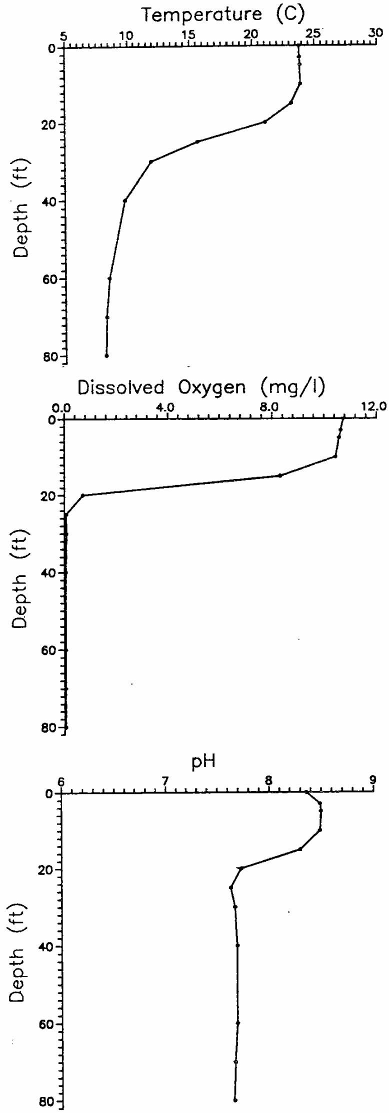


Figure 5. Winona Lake temperature, DO, and pH profiles (24 August 1989).

The pH distribution in the water column was representative of a productive stratified lake, with values above the thermocline higher than those below. The pH values above the thermocline ranged from 8.3 to 8.5. Below the thermocline, values ranged from 7.6 to 7.7. The higher pH values in the upper ten feet of water are a result of the photosynthetic utilization of carbon dioxide (CO_2), a weak acid. As CO_2 is utilized and its concentration in the water column is reduced, pH increases.

4.1.2 Chemical Measurements

Water quality analyses were conducted on both in-lake samples and tributary samples. Results for both types of samples collected are discussed below.

In-Lake Samples

The results of the water quality analyses for in-lake samples are presented in Table 11. Higher concentrations of TP, OP, TKN, N-NH_4, and TSS were found in the 55 foot sample than in either the mid-depth or surface samples. Although the 55 foot sample was collected approximately 25 feet above the bottom of the lake, the profile data (temperature, dissolved oxygen, and pH) indicate that conditions at this depth were nearly identical to those on the bottom of the lake. Nutrient concentrations were moderately high, but not surprising for northern Indiana lakes with largely agricultural watersheds.

Textbooks in limnology typically place lakes in one of three classes, depending on their trophic state. Oligotrophic lakes are least productive. Mesotrophic lakes are intermediate, and eutrophic lakes are most productive. Based on the secchi depth and nutrient data collected, Winona Lake falls within the eutrophic category. However, the lake compares favorably, (i.e., it had lower TP concentrations), with three other lakes sampled in Kosciusko County by IS&T on the same day (8/24/89): Pike Lake, Little Barbee Lake, and Ridinger Lake. TP concentrations in both surface and deep water samples from Winona Lake were far lower than in any of these three lakes. However, soluble nitrogen was approximately three times greater in the surface sample, and approximately seven times greater in the deep water sample, than in the other three lakes. These results point to the effectiveness of a sewer system in reducing total phosphorus inputs from lakeshore residents. Reasons for the high soluble nitrogen concentration are not clear from the limited sampling that was conducted, but it is likely that this is a results of inputs from lawns and parkland near the lake, and from upland sources in the watershed.

The ratio of total nitrogen to total phosphorus (N:P) is often used to evaluate the relative importance of these two algal nutrients, which are quickly taken up in their soluble forms (i.e., ortho-phosphorus and nitrate). Algae characteristically consume phosphorus in excess of their immediate physiological requirements. Nitrogen is rarely limiting (i.e., the first to be used completely following continued growth) in freshwater systems due to its abundance in the atmosphere and availability through nitrogen fixation by blue-green algae. The concentrations of the soluble forms, therefore, are not necessarily indicative of available supply (Welch, 1980). The ratio of the total nutrient concentrations, however, can

Table 11. Winona Lake water quality results for in-lake samples.

SAMPLE ID	SAMPLE DEPTH (ft)	DATE COLLECTED	TIME COLLECTED	CHL a (mg/m^3)	FECAL COLIFORM (#/100ml)	$N\text{-}NH_4$ (mg/L)	NO_3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)
W-SURF	0.0	08/24/89	8:00	10.25	2	<0.005	0.465	0.461	<0.005	0.017	1.75
W-MID	40.0	08/24/89	8:10	0.00	8	0.340	0.864	1.005	<0.005	<0.011	1.67
W-BOTM	55.0	08/24/89	8:25	2.24	0	0.570	0.800	1.064	0.055	0.057	2.33

CHL a = Chlorophyll a; FECAL COLIFORM = Fecal Coliform Bacteria; $N\text{-}NH_4$ = Ammonia; NO_3 = Nitrate;
TKN = Total Kjeldahl Nitrogen; OP = Ortho Phosphorus; TP = Total Phosphorus; TSS = Total Suspended Solids
< = Value Lower than Detection Limit

Table 12. Wate. quality results for Winona Lake tributaries.

BASEFLOW ANALYSES

SAMPLE ID	DATE COLLECTED	TIME COLLECTED	CHL a (mg/m^3)	$N\text{-}NH_4$ (mg/L)	NO_3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)
Wyland Ditch	08/29/89	22:00	35.87	<0.005	1.040	1.234	<0.005	0.110	69.14
Keefer-Evans	08/29/89	22:00	66.57	<0.005	0.293	1.615	0.033	0.177	29.71
Peterson	08/29/89	22:00	10.68	0.060	0.708	0.627	<0.005	<0.011	4.29
WL-#3	08/29/89	22:00	14.95	0.240	0.099	0.282	<0.005	<0.011	4.29

STORM EVENT ANALYSES

SAMPLE ID	DATE COLLECTED	TIME COLLECTED	CHL a (mg/m^3)	$N\text{-}NH_4$ (mg/L)	NO_3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	TSS (mg/L)
Wyland Ditch	11/15/89	16:00	9.40	<0.005	1.061	1.455	0.152	0.363	118.70
Keefer-Evans	11/15/89	16:10	4.49	0.087	1.725	0.938	0.018	0.011	10.60
Peterson	11/15/89	16:20	7.69	0.032	2.832	1.052	0.020	<0.011	51.30

CHL a = Chlorophyll a; $N\text{-}NH_4$ = Ammonia; NO_3 = Nitrate; TKN = Total Kjeldahl Nitrogen;
OP = Ortho Phosphorus; TP = Total Phosphorus; TSS = Total Suspended Solids;
< = Value Lower than Detection Limit

be used to assess which nutrient will be limiting to plant growth under optimal physical conditions where light and temperature are not inhibiting.

Knowledge of which nutrient is more important to lake productivity is important in developing management strategies for the lake and watershed. As a general rule, if the N:P ratio is 17 or greater, phosphorus is most likely the limiting nutrient. N:P ratios less than 13 are usually indicative of nitrogen limitation (Cooke, et. al., 1986). Either nitrogen or phosphorus may be limiting when ratios are between 13 and 17. The N:P ratios of the surface was 54.5. For the sample at 55 feet, the ratio was 32.7. Both values indicate that Winona Lake was phosphorus limited at the time of sampling. Most lakes in the north-temperate region of the country are phosphorus limited. Calculation of an N:P ratio for the mid-depth (40 ft.) sample was not possible, as the TP concentration in that sample was lower than the detection limit (i.e., < 0.011 mg/L).

Tributary Samples

Table 12 presents the water quality data for the Winona Lake tributaries under baseflow and storm event conditions.

Baseflow samples were collected on 29 August 1989 during low flow conditions typical of late summer. Water samples collected at this time are often considered "baseflow" samples. The concentrations of nutrients and other elements in the water during this period of the year are due largely to groundwater inputs, and are thus indicative of the effects of geology and/or soils on the water chemistry of these streams. It should be noted that flow measurements were not made in conjunction with either baseflow or storm event sampling. Thus, the loading, or quantity of nutrients or sediments reaching the lake, was not determined.

The concentrations of TP, OP, and TKN were higher in the Keefer-Evans sample than in either Wyland or Peterson Ditch samples. This can be attributed to the relatively smaller size, and potentially lower volume of flow, in this stream as compared to the other two major tributaries to the lake. Concentrations of nutrients, and other chemicals, would be expected to be less dilute, and thus in greater concentration due to the potentially lower volume of water in this ditch. Soluble nitrogen (NO_3) was highest in the Wyland Ditch sample. The level of TSS was also highest in the Wyland Ditch sample. This parameter is an important indicator of differences in the quantity of particulate material that is normally present in the stream. The TSS level in Wyland Ditch was more than 15 times that of Peterson Ditch. TSS was also relatively high in Keefer-Evans Ditch.

Storm event samples were collected from Wyland, Keefer-Evans and Peterson Ditches on 15 November 1989 during a storm of moderate intensity. Rainfall during this 24-hour period was 1.21 inches, less than half the maximum amount (2.4 inches) that can be expected to occur on a frequency of one year (U.S. Dept. of Commerce, 1966). Rainfall during the 24 hours prior to the date of sample collection was 0.06

inches. Precipitation data were recorded at the Warsaw, IN airport.

Storm event sample analyses revealed a general increase in nutrients (TP, OP, TKN, NO_3) and TSS concentrations in Wyland and Peterson Ditches, but a decrease in all parameters except NO_3 and N-NH_4 in Keefer-Evans Ditch. The decrease in concentrations for Keefer-Evans Ditch may be explained by watershed activities or the flushing effects of the storm event. All three tributaries had higher concentrations of NO_3 and TSS than were found in Winona Lake. Additionally, the TP, OP and TKN concentrations in Wyland Ditch were in excess of those found in Winona Lake.

4.1.3 Biological Measurements

The results of the chlorophyll a analyses indicate that the greatest amount of photosynthetic activity was occurring near the surface of the lake. The pigment concentration observed in the surface (10.25 mg/m^3) suggests productive waters. As expected, the Chla concentration in the 40 and 50 foot samples dropped sharply as light and temperature became limiting to phytoplankton.

The results of phytoplankton identification and enumeration for Winona Lake showed a diverse algal community of 23 species representing 4 classes (Table 13). The algal community was dominated by blue-greens, which comprised approximately 97 percent of the 5 foot tow and 96 percent of the 20 foot tow (Figures 6a and 6b). Numerically, the dominant algal specie was the blue-green algae Lyngbya birgei. Other numerically important species included the blue-greens Microcystis aeruginosa, and Anabaena flosaquae. Blue-green algal dominance is known to be indicative of eutrophic conditions.

Fecal coliform bacteria were present in the surface and mid-depth water column samples. The highest fecal count (8 colonies per 100 ml of sample) occurred in the mid-depth sample. All samples had counts well below the IDEM standard for whole body contact recreation in lakes and reservoirs (i.e., 400 colonies per 100 ml sample).

4.1.4 Trophic State Assessment

The biological, chemical and physical characteristics of a lake can be incorporated into an index number to describe its trophic state. Historically, trophic classifications have been based on the division of the trophic continuum into a series of classes. Traditional systems divide the continuum into three classes (i.e., oligotrophic, mesotrophic and eutrophic), but frequently offer no clear delineation of these divisions. Calculating a trophic state index allows a quantitative description of the degree of eutrophication in a lake, and provides a basis for numerically comparing the lake's trophic status over a period of time and for comparing its trophic state against that of other lakes.

There are several numerical trophic classification systems currently used within the scientific community. A previous trophic state assessment of Winona Lake was conducted using the BonHomme Eutrophication

Table 13. Winona Lake phytoplankton identification and cell count/ml (24 August 1989).

	CELLS PER SAMPLE	
	5 FT. TOW	20 FT. TOW
Sample Volume Total (ml)	87.0	167.0
Volume of sample settled for ident. (ml)	3.0	1.0
SPECIES		
Chlorophyta (green algae)		
Chlamydomonas snowii	823,000	202,000
Chlamydomonas sp	17,500	
Gloeocystis major		*
Pediastrum simplex	543,000	16,100,000
green flagellates	17,500	
Total Chlorophyta cells per sample	1,401,000	16,302,000
Total Chlorophyta cells per ml settled	16,104	97,617
Chrysophyta (diatoms, chrysophytes, etc.)		
Dinobryon sociale	350,000	807,000
Melosira granulata	228,000	3,020,000
Melosira sp	70,000	605,000
Navicula sp	*	202,000
centric diatoms < 10u		202,000
Total Chrysophyta cells per sample	648,000	4,836,000
Total Chrysophyta cells per ml settled	7,449	28,958
Euglenophyta (euglenoids)		
Total Euglenophyta cells per sample	0	0
Total Euglenophyta cells per ml settled	0	0
Pyrrophyta (yellow-browns)		
Ceratium hirudinella	35,000	
Cryptomonas erosa	17,500	403,000
Total Pyrrophyta cells per sample	52,500	403,000
Total Pyrrophyta cells per ml settled	603	2,413

Table 13. Winona Lake phytoplankton identification and cell count/ml. (24 August 1989 - concluded)

	CELLS PER SAMPLE	
	5 FT. TOW	20 FT. TOW
Sample Volume Total (ml)	87.0	167.0
Volume of sample settled for ident. (ml)	3.0	1.0
SPECIES		
Cyanophyta (blue-greens)		
Anabaena macrospora		12,900,000
Anabaena flosaquae		86,500,000
Anabaena planctonica		*
Aphanocapsa pulchra	70,000	4,030,000
Aphanothece gelatinosa	508,000	
Chroococus dispersus		1,610,000
Gomphosphaeria lacustris	770,000	8,470,000
Lyngbya birgei	54,300,000	171,000,000
Microcystis aeruginosa	*	103,000,000
Microcystis flosaquae		*
Oscillatoria limnetica		8,070,000
Oscillatoria tenuis	2,850,000	29,600,000
Oscillatoria sp	1,260,000	33,900,000
blue-green monads	87,600	50,400,000
blue-green filaments		2,460,000
Total Cyanophyta cells per sample	59,845,600	512,343,000
Total Cyanophyta cells per ml settled	687,900	3,067,925
Total phytoplankton cells per sample	61,904,710	533,880,000
Total phytoplankton cells per ml settled	712,056	3,196,913

* Species was found during scans of the subsample but not seen during the actual count.

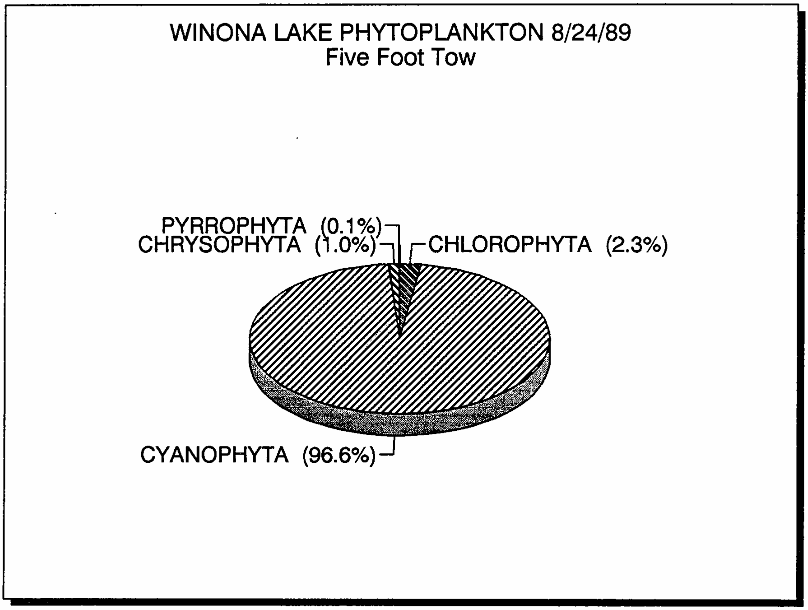


Figure 6a. Percentages of phytoplankton classes represented in the Winona Lake 5 foot tow.

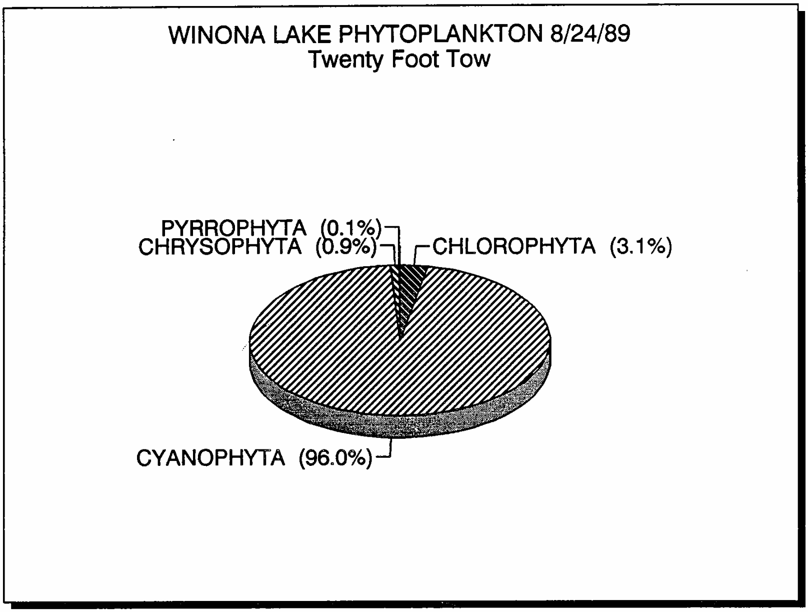


Figure 6b. Percentages of phytoplankton classes represented in the Winona Lake 20 foot tow.

Index and is documented in the Indiana Lake Classification System and Management Plan (IDEM, 1986). The index was developed by Harold BonHomme of IDEM. Index points are assigned based on diverse chemical, physical and biological measurements in the lake. A lake may receive a Eutrophication Index (EI) number ranging from 0 to 75, with values near 0 being the least eutrophic.

Another numerical index that is widely reported in the literature for trophic state assessment is the Carlson Trophic State Index (TSI). Carlson (1977) based his index on algal biomass using the log transformation of Secchi disk transparency, a physical measurement, as an estimate of biomass. Since Chla and TP concentrations are often correlated with transparency, a TSI number may also be calculated from these biological and chemical measurements. All three measurements are taken from surface waters where phytoplankton productivity is at its peak. The equations used for computing the Carlson TSI are:

$$TSI(SD) = 60(14.41 lnSD) \qquad (1)$$

Where:

TSI(SD) = TSI based on Secchi disk transparency

SD = Secchi transparency (m)

$$TSI(Chla) = (9.81 lnChla) + 30.6 \qquad (2)$$

Where:

TSI(Chla) = TSI based on chlorophyll concentration

Chla = Chlorophyll a (mg/m^3)

$$TSI(TP) = (14.42 lnTP) + 4.15 \qquad (3)$$

Where:

TSI(TP) = TSI based on total phosphorus concentration

TP = Total phosphorus (mg/m^3)

The Carlson TSI classifies lakes on a scale of 0 to 100, with each major scale division (i.e., 10, 20, 30, ...) representing a doubling in algal biomass. Under ideal circumstances, the three separate TSI values should be similar. Under realistic conditions, however, the index values will exhibit some variability. This variability reveals basic differences in the ecological functioning of the aquatic system. The accuracy of Carlson's TSI based on Secchi disk measurement alone is diminished by the presence of non-algal particulate matter or highly colored water. The index number derived from the Chla values, when available, is best for estimating algal biomass, and priority should be given for its use as a trophic state indicator (Carlson, 1977). The Carlson TSI results are shown in Table 14.

A BonHomme Eutrophication Index (EI) number was calculated for Winona Lake using the water quality and biological data collected during the 24 August 1989 field survey. The number of points assigned was based on the revised version of the EI scale. Table 15 presents the details of the calculation. There is one source of uncertainty in this EI calculation that should be noted. The phytoplankton sample from the thermocline was collected in a manner inconsistent with the technique used by BonHomme. A closed sample from the thermocline only, rather than a vertical tow from the thermocline to the surface, is the method used on lakes previously sampled by IDEM. Based on the recommendations of Mr. BonHomme (pers. comm.), the data collected from the 5 foot tow was used to estimate the phytoplankton count in the thermocline.

Previously, the IDEM calculated an EI number of 56 for Winona Lake. A re-evaluation of the data used for this calculation resulted in an EI number of 47 (BonHomme, pers. comm.). Additional data collected in 1987 by IDEM resulted in an index value of 40. The EI number based on data collected 24 August 1989 was calculated to be 48, placing the lake in the same trophic class (Class Two) previously assigned by IDEM. Class Two lakes have EI values from 26 to 50. Class Three lakes, which are most productive lakes in the State (poorest water quality) have values from 51 to 75. The EI value determined through this project is therefore near the upper boundary of Class Two.

Calculation of the Carlson TSI was based on the chlorophyll a and TP concentrations in the surface waters, as well as the Secchi disk transparency of Winona Lake. The range of TSI values was between 45 and 56. Lakes with TSI values between 40 and 50 are usually characterized by moderately clear water, and the increasing probability of anoxia in the hypolimnion during summer. As TSI values increase to the range of 50 to 60, water transparency decreases, the hypolimnion becomes anoxic during summer, and macrophyte problems become evident. Lakes with Carlson TSI numbers between 50 and 60 are characterized as the lower boundary of classical eutrophy.

Table 14. Carlson Trophic State Index calculations for Winona Lake.

SAMPLE DATE	SECCHI DISK (m)	TSI (SD)	CHLOROPHYLL (mg/m3)	TSI (Chla)	TP (mg/m3)	TSI (TP)
08/24/89	1.3	56	10.3	53	17	45

As seen in Table 14, a comparison of the TSI values show that Secchi disk and Chla based values are roughly equivalent and greater than the TP based value. This would indicate that light attenuation was dominated by algae, and the lake was phosphorus limited on the date of sampling (Carlson, 1983). Both the BonHomme EI and the Carlson TSI describe Winona Lake as being at the lower boundary of eutrophy. It should be noted that the data used to construct these indices are derived from a single sampling event and are only representative of lake conditions on a single day in mid-summer. Better

Table 15. BonHomme Eutrophication Index calculations for Winona Lake (24 August 1989).

Parameter and Range	Range Value	Range Observed	Point Value
Total Phosphorus (mg/L)			
Observed Mean: 0.02			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4		0
Greater than 0.99	5		0
Soluble Phosphorus (mg/L)			
Observed Mean: 0.02			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4		0
1.00 or more	5		0
Organic Nitrogen (mg/L)			
Observed Mean: 0.5			
At least 0.05	1	X	1
0.60 to 0.80	2		0
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/L)			
Observed Mean: 0.7			
At least 0.30	1		0
0.40 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Ammonia (mg/L)			
Observed Mean: 0.3			
At least 0.30	1	X	1
0.40 to 0.50	2		0
0.60 to 0.90	3		0
1.0 or more	4		0
Percent oxygen saturation at 5 feet			
Observed Value: 128%			
114% or less	0		0
115% to 119%	1		0
120% to 129%	2	X	2
130% to 149%	3		0
150% or more	4		0

Table 15 BonHomme Eutrophication Index calculations for Winona Lake (24 August 1989 - concluded).

Parameter and Range	Range Value	Range Observed	Point Value
Percent of Water Column with at least 0.10 mg/L of DO			
Observed Value: 31%			
28% or less	4		0
29% to 49%	3	X	3
50% to 65%	2		0
66% to 75%	1		0
76% to 100%	0		0
Secchi Disk Transparency			
Observed Value: 4 ft.			
5 feet or less	6	X	6
Greater than 5 feet	0		0
Light Transmission at 3 feet			
Observed Value: 36%			
0% to 30%	4		0
31% to 50%	3	X	3
51% to 70%	2		0
71% or greater	0		0
Total Plankton from 5 foot Tow (#/L)			
Observed Value: 557,110			
Less than 4700/L	0		0
4701/L to 9500/L	1		0
9501/L to 19,000/L	2		0
19,001/L to 28,000/L	3		0
28,001/L to 57,000/L	4		0
57,001/L to 95,000/L	5		0
More than 95,000/L	10	X	10
Blue-green dominance	5	X	5
Total Plankton from Thermocline Tow (#/L)			
Observed Value: 557,110			
Less than 9500/L	0		0
9501/L to 19,000/L	1		0
19,001/L to 47,000/L	2		0
47,001/L to 95,000/L	3		0
95,001/L to 190,000/L	4		0
190,001/L to 285,000/L	5		0
More than 285,000/L	10	X	10
Blue-green dominance	5	X	5
Population of 950,000 or more	5		0
			==
INDEX VALUE			48

representation of trophic state could be attained through increased lake monitoring throughout the summer growing season. Such high resolution sampling was beyond the scope of this investigation.

4.1.5 Sediment Sample Results

The results of the analyses on sediment samples collected from the tributaries to Winona Lake are shown in Table 16. The samples were collected 22 November 1989. For comparison purposes, this table also

Table 16. Winona Lake sediment sample analyses (samples collected 22 November 1989).

SAMPLE ID	TIME COLLECTED	TP (mg/Kg)	TKN (mg/Kg)	% SAND	% SILT	% CLAY
Wyland - #1	12:05	260	85			
Wyland - #2	12:10	120	59			
Wyland - #3	12:15	190	32	100	0	4
Wyland - #4	12:20	240	91	100	0	0
Wyland - #5	12:25	240	110	94	6	0
Wyland - #6	12:30	300	290	100	0	0
Wyland - #7	12:35	240	100	100	0	0
Keefer-Evans - #1	11:05	410	8,500			
Keefer-Evans - #2	11:10	500	710			
Keefer-Evans - #3	11:15	94	220			
Keefer-Evans - #4	11:20	570	230			
Keefer-Evans - #5	11:25	360	91			
Keefer-Evans - #6	11:30	1,170	6,800			
Keefer-Evans - #7	11:35	310	720			
Peterson - #1	10:05	410	84			
Peterson - #2	10:10	610	150			
Peterson - #3	10:15	370	140			
Peterson - #4	10:20	510	110			
Peterson - #5	10:25	340	83			
Peterson - #6	10:30	360	86			
Peterson - #7	10:35	440	99			
IDEM Background Level		610	1,500			

shows mean background concentrations of TP and TKN in sediments at 83 sites throughout Indiana, surveyed by IDEM from 1985 to 1987 (Indiana 305B Report, 1986-1987). These mean values represent sediment concentrations at sites upstream of all known point sources of pollution, including industrial discharges and combined sewer overflows. As such, they are considered to represent unpolluted lake and stream sediments statewide. The IDEM provides these estimates because no criteria for sediment concentrations of nutrients or priority pollutants have been established by the state or federal government.

As guidelines for interpreting sediment data, IDEM has defined four levels of concern: low, medium, high, and unknown. Low concern is defined as 2-10 times background levels, medium concern as 10-100 times background, and high concern as any concentration greater than 100 times background.

Using the IDEM guidelines, all results obtained are in the low concern category. The maximum factor by which a parameter exceeded the background level was 5.7 for TKN in sample #1 from Keefer-Evans Ditch. This sample was located along the Keefer-Evans Ditch inflow, approximately 100 feet upstream of the lake. A TKN concentration of 8,500 mg/Kg was measured at this site. The second highest sediment TKN concentration was also found along the Keefer-Evans Ditch inflow. This site (#6) is located approximately 50 feet into the lake and 50 feet west of the mouth of the ditch. Sediment TKN in this sample measured 6,800 mg/Kg, or 4.5 times the background level. Sediment TP concentrations were also highest in sample #6, measuring 1.9 times the background level (i.e., 1,170 mg/Kg).

The results of the particle size analyses for the Wyland Ditch samples indicated that sand was the dominant particle size for all five samples, comprising from 94 to 100 percent of the total sediment composition. Resuspension following a disturbance to the lake bottom, such as dredging, would therefore be expected to have minimal and short term effects on water clarity.

Accurate measurement of sediment depth, through the use of a sediment probe, was not possible. The sand bars at Wyland and Peterson Ditches consisted of coarse sand deposits that provided too much resistance for probing. Sediment probing was only possible at Keefer-Evans Ditch. Refusal depths, however, could not be determined as the probe was not rejected. The subsurface appeared as soft as the upper layer of sediment.

4.1.6 Bathymetric Survey

Bathymetric maps of the mouths of Peterson Ditch and Wyland Ditch are shown in Figures 7 and 8, respectively. At Peterson Ditch, 1.5 acres were surveyed. Water depths, in this area, ranged from less than one foot to 13 feet deep, with the deepest portions occurring approximately 275 feet into the lake. Water depths within the 4.6 acres surveyed at Wyland Ditch, ranged from less than one foot to 16 feet deep. The 16 foot depths occurred approximately 290 feet into the lake.

Sediment accumulation was determined only for the Wyland Ditch inflow, using the method described in Section 3.1.5. The calculations indicate a large accumulation of sediment near this inflow. Within the 4.6 acres surveyed, an accumulation of 15.8 acre-feet was calculated. This equates to approximately 3.4 feet of sediment, accumulated at a rate of 1.72 inches per year since 1965.

Additional bathymetric data were collected at the Keefer-Evans Ditch inflow. The area was uniformly shallow and there was no evidence of sedimentation, e.g., a bar or delta, in the immediate area.

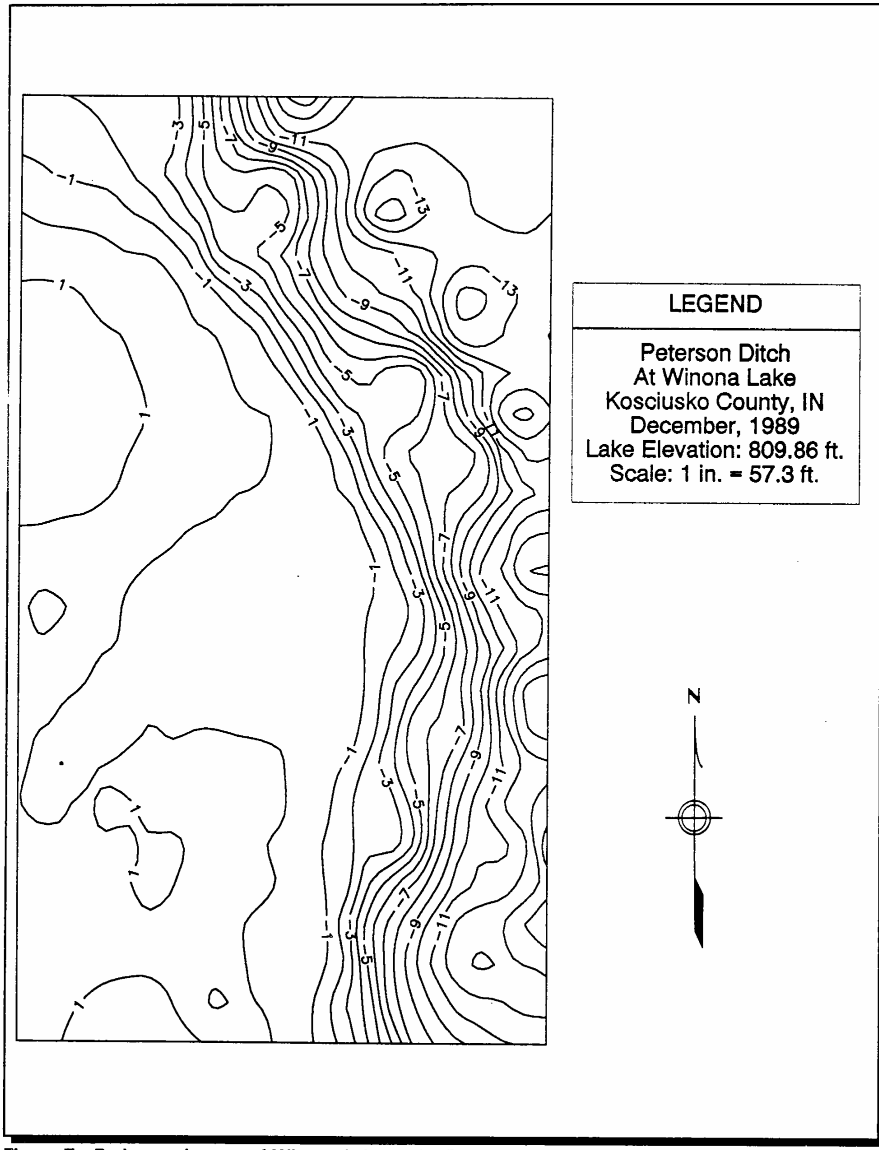


Figure 7. Bathymetric map of Winona Lake at the Peterson Ditch inflow.

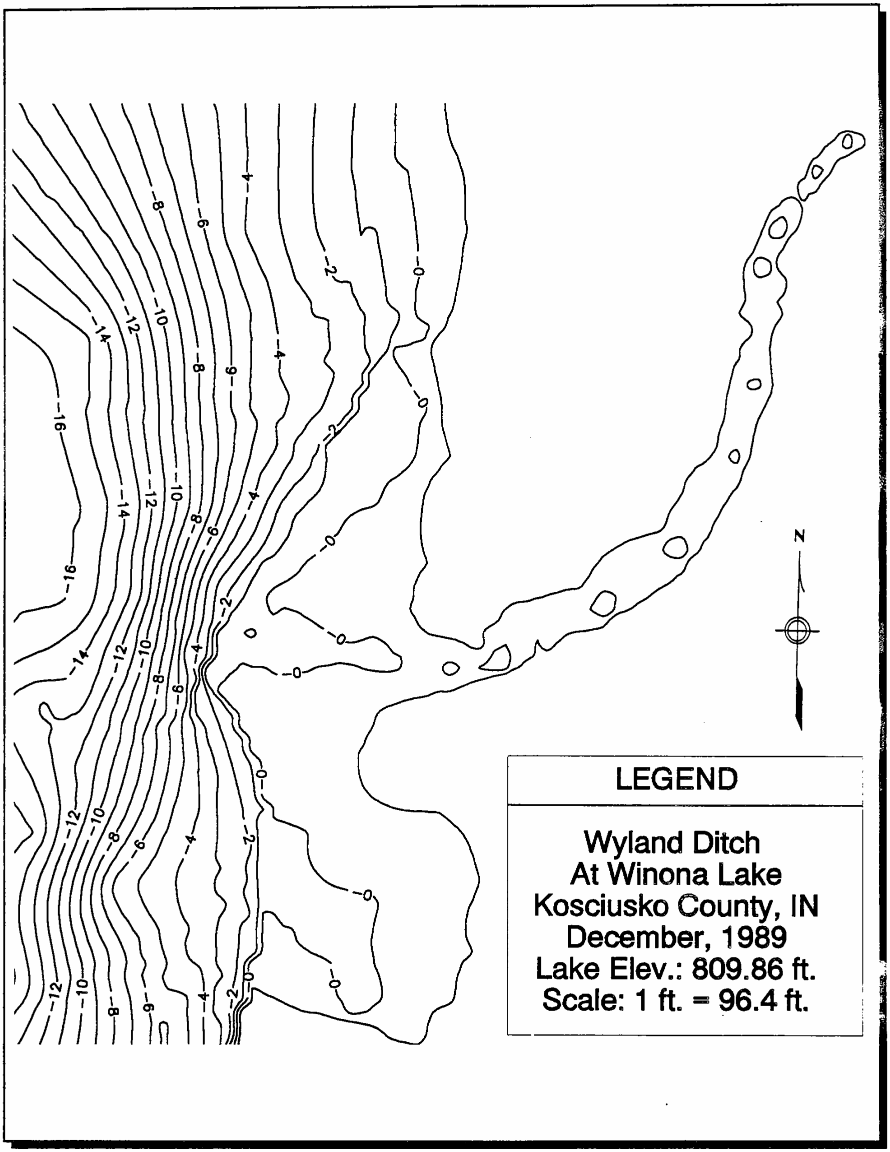


Figure 8. Bathymetric map of Winona Lake at the Wyland Ditch inflow.

4.2 WATERSHED SURVEY

The watershed survey examined hydrology, stream channel characteristics, land use, and erodible soils. The AGNPS model served as an important tool for integrating the effects of these factors on nutrient and sediment loading to the lake and interpreting their significance.

4.2.1 Hydrologic Results

With respect to lake restoration, the principal hydrologic parameter of interest in characterizing Winona Lake is the hydraulic residence time, defined as the length of time required for the entire volume of the lake to be replaced with "new' water from runoff and direct precipitation. This parameter defines how dynamic the system is and how responsive a lake will be to changes in nutrient loading.

For this study, hydraulic residence time was computed as the ratio of lake water volume to the net annual inflow water volume. The formula used in calculating retention time (τ) is as follows:

$$\tau = \frac{V}{R+P-E}$$

Where:

τ = Hydraulic retention time (years)
V = Lake volume (acre-feet)
R = Average annual runoff (acre-feet/year)
P = Precipitation (acre-feet/year)
E = Evaporative losses (acre-feet/year)

Average annual runoff for the Winona Lake watershed was determined by multiplying the watershed area by the average annual runoff value of 12.26 inches (1.02 feet) reported for Walnut Creek near Warsaw, IN (USGS 1988).

In addition to runoff from the watershed, the lake receives inputs from precipitation and loses water volume through evaporation. Average annual rainfall for the Kosciusko County area is 37 in/year (USGS, 1988). Thus, direct precipitative input to the lake was estimated to be 1,733 acre-feet per year. Evaporative losses from lake surfaces in northern Indiana are approximately 32 inches/year (Geraghty et. al., 1973) or approximately 1,499 acre-feet for Winona Lake. Thus, there is a net increase of five inches (0.42 feet), or approximately 234 acre-feet of water added to the lake annually (i.e., the difference between direct precipitative input and evaporative losses).

The hydraulic residence time for Winona Lake was calculated to be 0.87 years (318 days), a relatively long retention period. Longer water residence times (i.e., 100 days to several years) provide ample time for algal biomass to accumulate, given sufficient nutrient concentrations (USEPA, 1988). From the perspective of lake restoration, Winona Lake is likely to have a relatively slow response to a reduction in external nutrient loading. However, many lake restoration techniques require longer retention times for cost effective treatment.

4.2.2 Stream Channel Characterization

The objective of this aspect of the project was to characterize the major Winona Lake tributaries with respect to channel stability, sediment supply, and sediment transport. The following discussions are intended to serve as points of departure for future work on these streams, and to develop management alternatives for sediment related problems in Winona Lake. The three tributaries were surveyed in November 1989 using the Rosgen Stream Classification System, as described in Section 3.2.2. Stream channel characteristics for all three tributaries are shown in Table 17.

Table 17. Stream channel characteristics for Winona Lake tributaries (November 1989).

	Wyland[1] Ditch	Wyland[2] Ditch	Keefer-Evans Ditch	Peterson[3] Ditch	Peterson[4] Ditch
Rosgen Classification	F-4	C-3	C-5	C-3	C-3
Slope	<1.0%	>1.0%	<0.1-0.2%	0.33%	<0.5%
Width:Depth Ratio	10-40	25-30	10-12	58	22
Sinuosity	1.4	1.8	2.5+	>2.0	2.0
Dominant Particle Size	Sand-bed w/ smaller amts. silt & gravel.	Gravel bed w/sand & silt banks.	silt/clay	Gravel bed with sand & silt banks.	
Confinement	Good	Poor	Slight	Slight	Slight

[1] Upper reaches of Wyland Ditch, north of C.R. 450 South.
[2] Lower reaches of Wyland Ditch.
[3] Peterson Ditch immediately upstream of Winona Lake.
[4] Peterson Ditch at Country Club Road.

The term sediment, as it is used in this study, refers to the entire range of materials, regardless of size, that become suspended and are transported by flowing streams and rivers. The study of sediment transport is an active area of research in watershed science. Understanding the erosion process in streams and rivers is necessary to develop watershed management strategies, particularly if bars, shoals, degrading banks and other signs of excess sediment supply are evident.

Streams form and maintain channels capable of carrying the runoff volume that occurs approximately annually. When this annual, or bank-full flow occurs, the majority of sediment that is transported on an annual basis is moved through the system. At flows less than three-fourths bank-full, the stream does not move appreciable amounts of sediment. A "stable" stream is one in which sediment supply is in balance with the stream's ability to carry the bank-full load without degradation of the banks, or a change in gradient or slope. This situation, in which a balance exists between sediment supply and transport, is considered an equilibrium condition.

If a change in sediment supply or volume of runoff occurs, the stream system is thrown out of equilibrium. For example, if construction activities in the watershed increase the amount of sediment entering the stream, there must be adjustments to the physical characteristics of the stream to allow the bank-full volume to be carried. The most common adjustment in low gradient streams, common in northern Indiana, is bank erosion. The process of adjusting to the increased sediment load forces the stream to erode the outside bank, which in turn "carves out" more sediment from the bank itself, particularly if the bank material consists of erodible soils. Given the natural meandering pattern of streams, this process cannot be confined to a single location, and continues as a kind of chain reaction in which downstream outside banks are sequentially eroded as more material is added at every turn of the stream. Thus, the original sediment added to the stream is multiplied many times in the process of accelerating downstream erosion. The process of "recovery" to an equilibrium condition may take many years, during which the stream channel is carrying excess sediment to the receiving water body.

Wyland Ditch

As a result of earlier work on Winona Lake (Hippensteel, 1989), Wyland Ditch was suspected of contributing excessive quantities of sediment to the lake. Based on the information collected during the November 1989 survey, there was little or no evidence that this situation remains, however problems were seen in isolated reaches. The majority of Wyland Ditch was characterized as an F channel, which had been ditched in the past. F type channels are usually very well confined, and have unstable beds which create poor conditions for fish and aquatic invertebrates due to the continually shifting sands. Even the riffle areas of most F type channels are imbedded with fine sized materials. Reduction of upstream sources of sediment is the most effective restoration strategy for this stream type. Additional measures include channel grade control and bank stabilization. Grade control could be accomplished through low stage check dams (height no greater than 20 percent of bankfull depth) placed in straight reaches.

Wyland Ditch upstream of C.R. 225 South, in the vicinity of the Stonehenge Golf Course, was suspected of contributing large quantities of sediment to Winona Lake, however there was no evidence of freshly deposited sediment or in-channel sediment bars in this area. The banks were well stabilized with vegetation and showed no evidence of accelerated erosion. Bank erosion was evident near the intersection of C.R. 400 South and C.R. 400 East. At this site, noticeable rejuvenation was occurring both upstream and downstream of the culvert, and the unstabilized eroding banks reached heights up to fifteen feet. Further down stream, at C.R. 450 South, there was, again, no evidence of channel erosion or high sediment supply.

The lower reach of Wyland Ditch was characterized as a C-3 channel type. C-3 streams usually provide good habitat for fish and aquatic invertebrates. The size of the streambed material is coarse and variable enough to provide a variety of habitat conditions suitable for spawning, feeding, and resting. Due to greater width to depth ratios, these streams may have a shortage of deep water areas during summer low flows. Areas that do not have sufficient depth at low flow can be enhanced with habitat improvement measures such as low profile deflectors or bank imbedded boulders. Both of these measure create pool conditions at low flows. Another characteristic of C-3 streams is that they are easily destabilized by large inputs of suspended sediment. The response to an increase in sediment loading is the formation of in-channel bars and lateral adjustment, i.e., bank erosion. This process adds even more sediment creating similar conditions downstream.

Installation of a sewer line in the flood plain in the lower section of Wyland Ditch has resulted in a situation similar to that described above. Excess sediment from a spoil pile left after the sewer installation was completed, and from an unstable area where wetlands had been excavated were the apparent sources of the problems seen. Gullies had formed and were carrying sediment into Wyland Ditch, creating in-channel bars and imbedded fines in gravel riffles. The observed condition did not appear to be serious, however continued observation is merited. This portion of the ditch will respond to increasing in-channel bar formation by undergoing lateral adjustment, resulting in sediment yield from the stream banks in excess of the amount input from overland sources.

Because Wyland Ditch did not appear to have a serious erosion and sediment supply problem, an investigation of historical aerial photographs of Winona Lake, near the mouth of Wyland Ditch, was conducted. The appearance of the large depositional bar at the mouth of Wyland Ditch has not changed significantly in the last 15 to 20 years, and in fact may have been slightly larger in the past. It was concluded that the sediment buildup in Winona Lake, due to Wyland Ditch inputs, has been a gradual process occurring over many years, rather than a greatly accelerated process occurring in the recent past.

Keefer-Evans Ditch

Keefer-Evans Ditch was also evaluated for bank stability and evidence of its sediment supply-sediment transport balance. The Ditch was classified as a C-5 channel type in its lower reaches. The width to depth ratio of C-5 streams is less than C-3, i.e., the streams are narrower and deeper. Dominant particle size is silt/clay, and the streams have low gradients (less than 0.1% to 0.2% slope). Habitat suitability is lower for this stream type than for the C-3 channel at Wyland Ditch and at Peterson Ditch (see below). There was no evidence of accelerated erosion or bank instability associated with this ditch.

Peterson Ditch

Peterson Ditch was classified as a C-3 Channel type using the Rosgen Stream Classification System. Extensive bank erosion and mid-channel bar formation was found within the lower one and one half mile of this tributary. Until it is stabilized, this section of Peterson Ditch will be a significant source of sediment to Winona Lake. The erosion that is occurring will accelerate as the banks supply more sediment to the stream, which is already unable to transport all of the sediment that is supplied to it. Restoration of the natural channel geometry and stabilization using native materials from the immediate area is recommended (see Section 9).

4.2.3 Land Use Characterization

One of the most influential factors governing the quality of a surface water body is the nature of land use in the drainage basin. Land use characterization within the Winona Lake watershed was critical in determining the input parameters for the AGNPS model. The different land use categories and corresponding percentages of areal coverage are listed in Table 18. A land use map is presented in Figure 9.

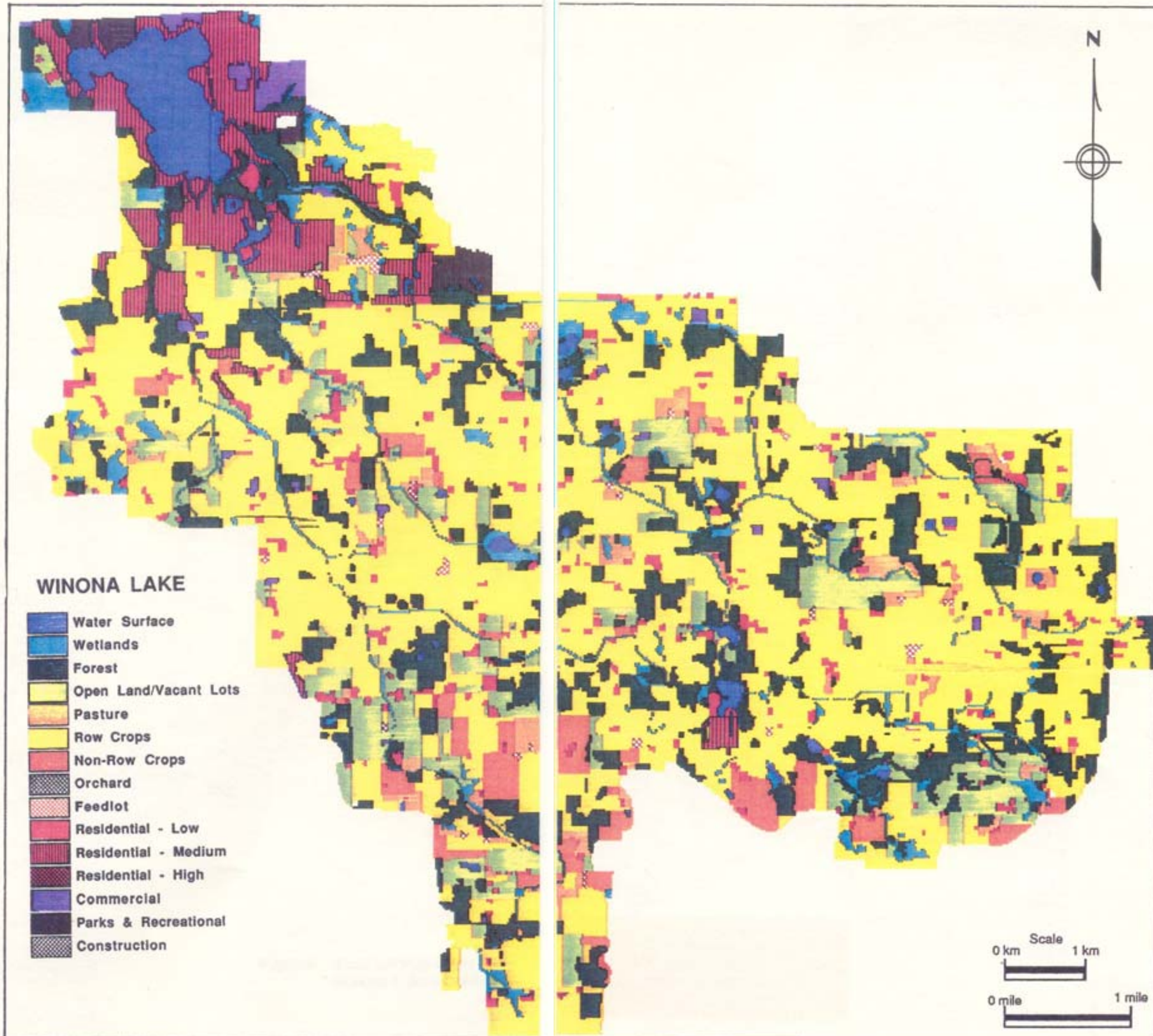
Table 18. Land use percentages for the Winona Lake watershed.

CATEGORY	PERCENT OF WATERSHED
Water	3.3
Wetlands	4.4
Forest	13.9
Open	9.2
Pasture	2.2
Row Crops	52.3
Non-row Crops	3.1
Orchards	0.0
Feedlots	0.4
Low Density Residential	3.4
Medium Density Residential	5.8
High Density Residential	0.0
Commercial	1.0
Institutional/Parks	0.8
Bare/Unseeded Ground	0.0
Resource Extraction/Excavation	0.2

The primary land use within the watershed was row crop agriculture, accounting for 52.3% of the total acreage. Blocks of row crops were found uniformly dispersed throughout the entire drainage basin. This large percentage of land presents the most significant potential source of sediment and nutrient loading to Winona Lake. Forested land constituted 13.9% of the watershed area and was also found dispersed throughout the drainage basin. Non-row crop agriculture comprised only 3.1% of the total watershed area. Wetland areas, accounting for 4.4% of the drainage basin, and feedlots (0.4%) were also found throughout the watershed.

The three residential use categories together accounted for 9.2% of the watershed. Areas of low density residential use (i.e., one unit per acre) were found throughout the watershed, while areas of medium density residential use (i.e., two to five units per acre) were located primarily in the vicinity of Winona Lake. There were no areas of high density (i.e., six or more units per acre) residential use identified.

Figure 9. Land use map of the Winona Lake watershed.


N
WINONA LAKE
Water Surface
Wetlands
Forest
Open Land/Vacant Lots
Pasture
Row Crops
Non-Row Crops
Orchard
Feedlot
Residential - Low
Residential - Medium
Residential - High
Commercial
Parks & Recreational
Construction
Scale
0 km
1 km
0 mile
1 mile

4.2.4 Erodible Soils Evaluation

The "Northeast Indiana Erosion Study" (USDA, 1988) cited loss of soil productivity, prevention of small plant growth, and contribution of soil to ditches as three primary problems associated with soil erosion. The study identified major erosion problem areas and rates of erosion in 14 counties in northeastern Indiana, including Kosciusko County. Problem areas are defined in the reports as areas "with a predominance of land that is eroding substantially in excess of rates at which it will maintain its' productivity". The results of the USDA report were used to identify problem areas in the Winona Lake watershed.

The USDA estimate of soil erosion in Kosciusko County was 9.9 tons/acre/year (265 yd^3/acre/year): 5.8 tons (155 yd^3) from sheet and rill erosion, 3.1 tons (83 yd^3) from wind, and one ton (27 yd^3) from gully erosion. Based on this information, the Wyland Ditch portion of the watershed would then contribute approximately 87,000 tons (2,327,000 yd^3) of sediment per year. Concurrently, the Keefer-Evans Ditch portion would contribute 29,000 tons (773,000 yd^3), and the Peterson Ditch drainage area would contribute 69,500 tons (1,860,000 yd^3).

In a preliminary investigation of Kosciusko County lakes, Hippensteel (1989) evaluated erodible soils in the Winona Lake watershed. This study identified specific highly erodible soil types and their location, rather than the more broadly defined problem areas in the USDA study. Hippensteel identified highly erodible soils in 34.5% of the entire drainage basin. Erodible soils comprised 39.6% of the Wyland Ditch drainage basin, 23.2% of the Keefer-Evans Ditch drainage area, and 32.8% of the Peterson Ditch watershed. Heavy concentrations of highly erodible soils were found throughout the southern reaches of the drainage basin, and contiguous with the shoreline of all three tributaries in many areas.

4.2.5 Sediment and Nutrient Modeling

This section of the report describes the results of the AGNPS modeling effort. Prior to running the model, it was necessary to divide the watershed into a grid of equally sized areas, or "cells". This grid was prepared by subdividing each 640 acre section (one square mile) into eight 80-acre cells. These cells were then further subdivided to yield 16 40-acre cells per section. In some cases, the 40 acre cells were further sub-divided to yield four 10-acre cells. As with the "parent" group of cells, which are numbered from west to east beginning at the northern-most point in the watershed, the sub-cells are assigned numbers based on their location within the larger cell. For example, cell 216 was sub-divided to yield four 10-acre cells: #216-100, located at the northwest corner of cell #216, through #216-400, located at the southeast corner of cell #216. The AGNPS cell grid for the Winona Lake watershed is shown in Figure 10. The watershed contains 451 40-acre cells.

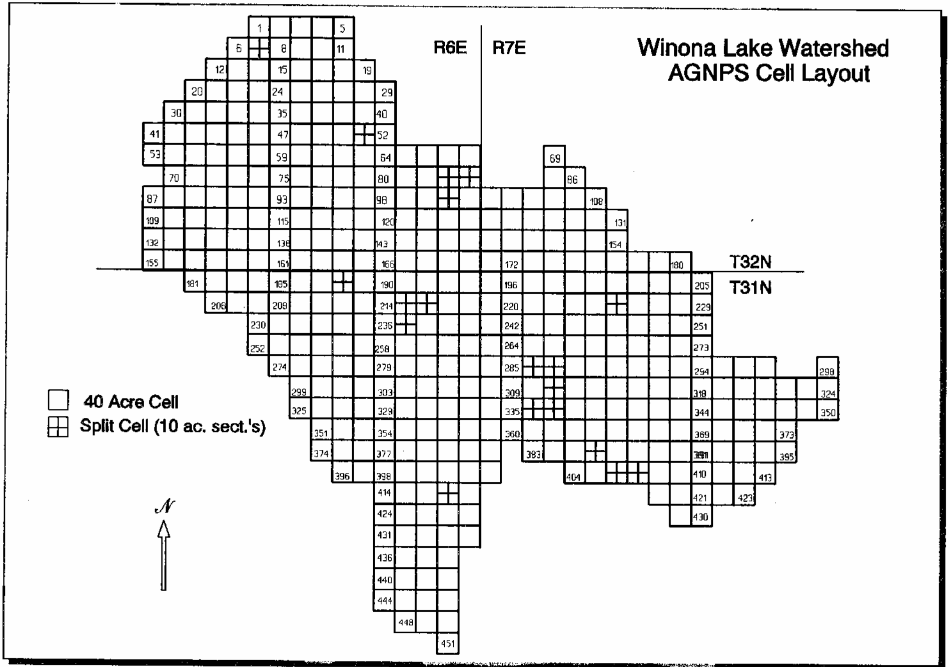


Figure 10. AGNPS cell layout for the Winona Lake watershed.

Data characterizing the physical features of the cells were utilized by the model to describe the sediment and nutrient contributions of each cell. This information was used to identify cells that were responsible for disproportionate sediment and nutrient export to the lake. Four categories of AGNPS output were evaluated in describing the pertinent export features: (1) sediment yield, (2) cell erosion, (3) nutrient loading, and (4) hydrology. The AGNPS model was run on one distinct scenario: a U.S. Weather Bureau defined, Type Two, two year, 24 hour storm during the spring growing season. The modeled storm produced 2.7 inches of rainfall during the 24-hour period.

The Winona Lake watershed consists of approximately 18,000 acres of primarily agricultural land. Channelized flow to the lake comes from three primary ditches and numerous secondary ones. Several small lakes are located within the watershed. While this modeling exercise does not specifically address the influence of these lakes on the watershed, they have been characterized within the model. As with any lake that interrupts the continuous flow of a tributary, the smaller lakes within the Winona Lake watershed act as sediment traps. Although this may be deleterious to the lakes themselves, they have a beneficial effect on winona Lake by reducing the quantity of sediment and nutrients reaching the lake.

In addition to the maps produced showing areas of greater sediment and nutrient loading in the entire watershed, sediment yield and nutrient loading were expressed for each of the major sub-basins of the Winona Lake watershed: Wyland Ditch, Keefer-Evans Ditch, and Peterson Ditch sub-basins. The areas included within each of the three sub-basins are shown in Figures 11, 12, and 13. Comparison of sediment and nutrient loading among these larger areas provided a means for prioritizing problem areas based on hydrologic units within the Winona Lake watershed.

Sediment Yield and Erosion

Sediment yield from each AGNPS cell is the amount of sediment, in tons, that leaves a cell at its downstream edge. This figure represents the sediment generated inside the cell plus the sediment from upstream cells, minus deposition within the cell.

Cell erosion refers to the amount of sediment that is produced by the storm event within an individual cell rather than the cumulative amount passing through the cell. The most important factors contributing to erosion within a given cell are soil erodibility (i.e., K-factor) and land slope. Land use, water flow velocity, and the presence/absence of defined stream channels within a cell also influence erosion. Areas of intense row-crop agriculture generally produce higher erosion rates than forested or wetland areas. Table 19 lists the cells with the highest cell erosion rates in the Winona Lake watershed, and gives the pertinent factors influencing these rates.

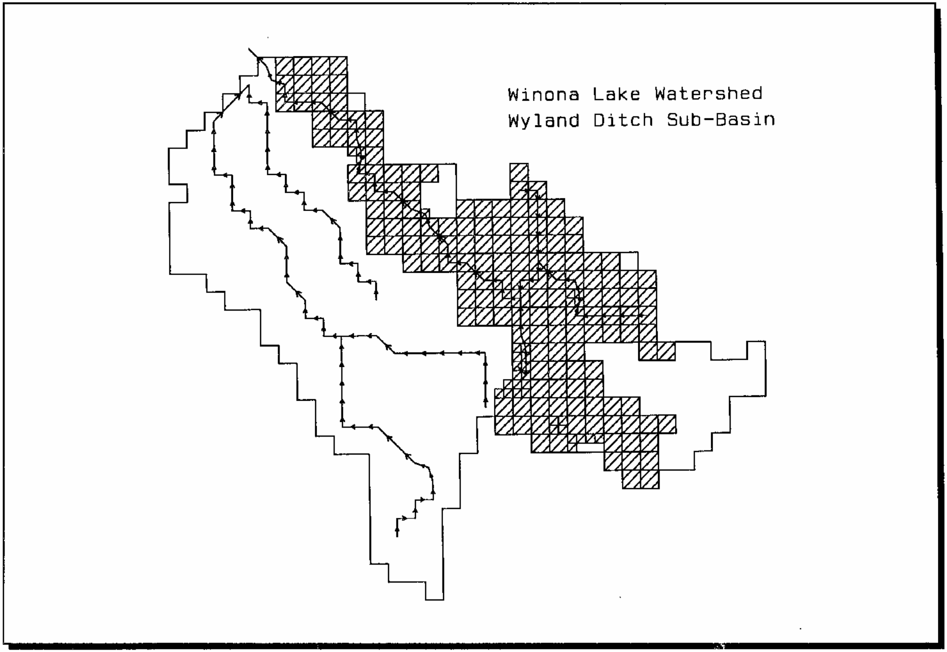


Figure 11. Wyland Ditch sub-basin of the Winona Lake watershed.

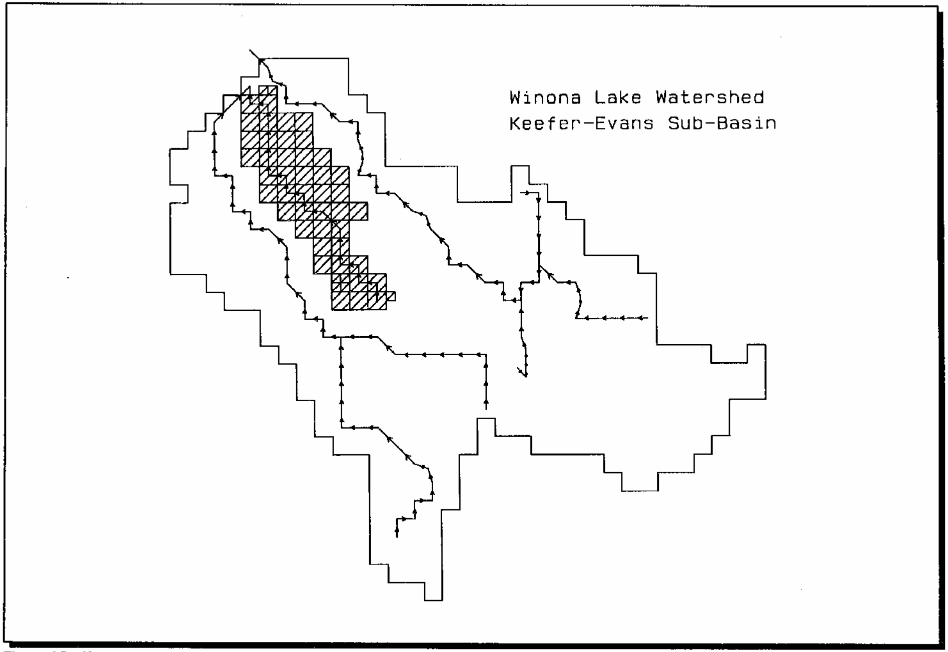


Figure 12. Keefer-Evans Ditch sub-basin of the Winona Lake watershed.

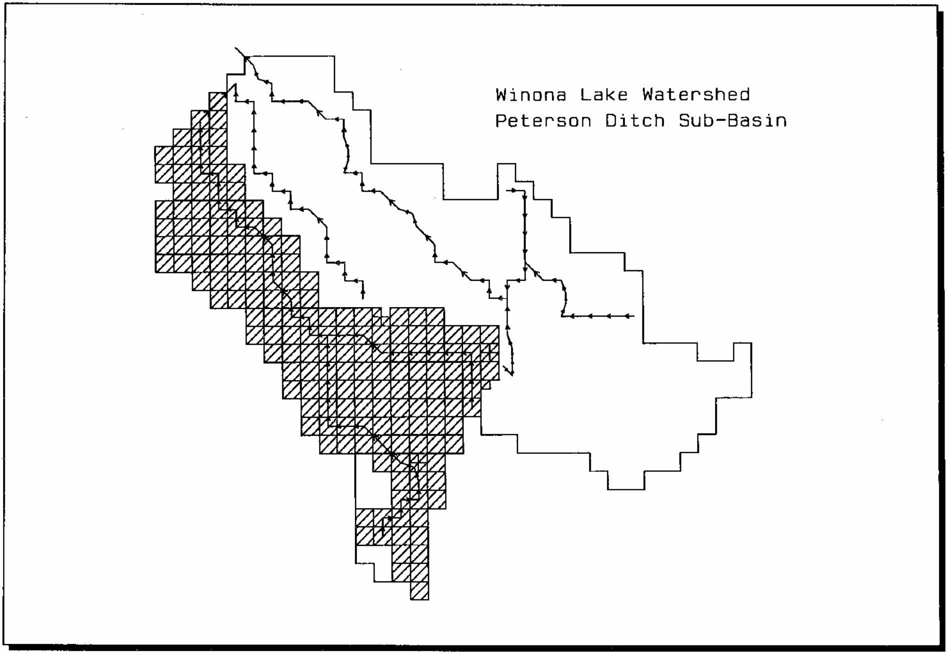


Figure 13. Peterson Ditch sub-basin of the Winona Lake watershed.

Table 19. Physical characteristics of selected cells in the Winona Lake watershed.

Cell #	Erosion (tons/acre)	Sediment Yield (tons)	Percent Row Crop	K Factor	Slope %
152	3.68	154.28	90.43	0.32	6.9
229	3.05	91.35	92.28	0.37	6.4
285	3.62	289.62	79.63	0.37	8.7
308	3.43	89.96	67.54	0.37	11.5
313	3.34	229.34	75.44	0.37	7.2
334	3.59	97.48	72.22	0.43	7.7
335	3.34	221.83	54.01	0.43	11.8
360	3.02	82.52	81.48	0.43	6.7
361	3.40	113.32	89.81	0.43	8.5
438	4.53	239.91	34.57	0.37	14.5

It was necessary to examine cell erosion and sediment yield in order to distinguish source areas from conduit, or "flow-through" areas. Management options exist for both source and downstream sediment control, so the distinction is often an important one. Watershed cells with high sediment yield and high cell erosion are displayed in Figures 14 and 15, respectively.

The total sediment yield into Winona Lake was calculated at 922.32 tons. The amount of sediment yield from each cell ranged from no yield to 530.50 tons. The cell with the highest sediment yield was cell #31. This cell is divided diagonally by CR 225 South at the point where it curves northeast, crosses Peterson Ditch and proceeds towards Warsaw. While the sediment generated within cell #31 was less than 46 tons, the amount of sediment entering the cell from upstream sources was significant, 533.11 tons, or 58% of the total sediment entering Winona Lake during the modeled storm.

Cell #31 represents the northernmost cell within the watershed that is dominated by agriculture and that is drained by Peterson Ditch. In addition, this cell has a large (7,560 acres) subwatershed that consists mainly of agricultural land use. The location of this cell within the overall drainage scheme of Winona Lake, rather than its physical characteristics, explains the high sediment yields predicted by the AGNPS model. Specifically, the modeled sediment yield from cell #31 was the result of 3 factors:

1) A large sub-basin that focused runoff at cell #31
2) Land uses conducive to high sediment export within cell's sub-basin
3) Channelized flow from Peterson Ditch transporting sediment from upstream sources.

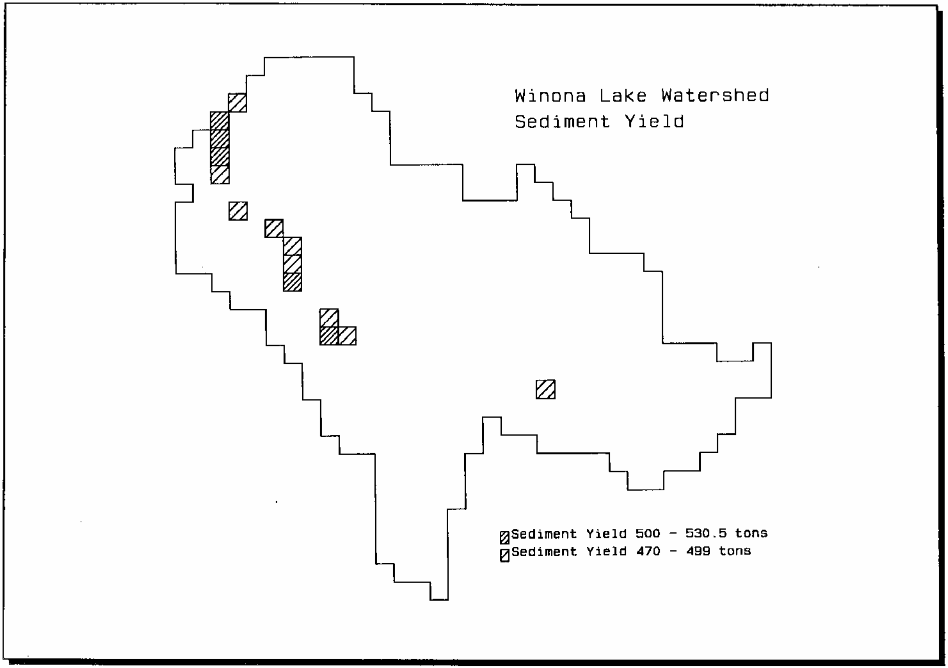


Figure 14. Modeled sediment yield for the Winona Lake watershed.

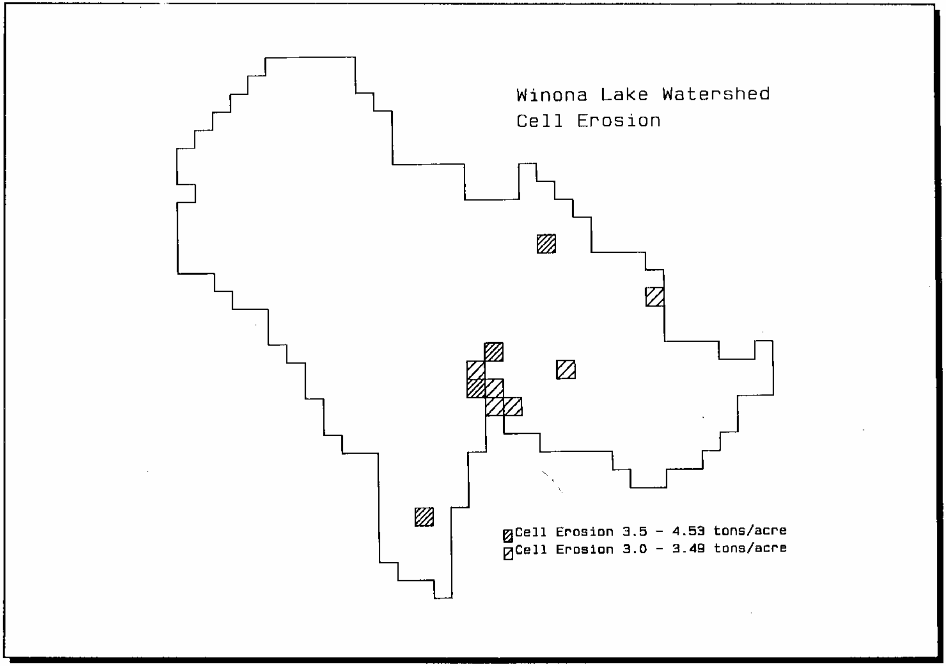


Figure 15. Modeled erosion rates for the Winona Lake watershed.

Four other cells in the watershed had sediment yields in excess of 500 tons: cell #20, cell #43, cell #185, and cell #255. Cells 20 and 43 are located directly north and south, respectively, of cell #31. Cell #185 is bordered to the west by the Packerton Road and to the north by 400 South Road. Cell #255 is bordered on the east by 200 East Road and is located approximately 600 feet south of 400 South Road. All four of these cells are intersected by Peterson Ditch. The AGNPS model, therefore, indicates that a major avenue of sediment export to Winona Lake is through Peterson Ditch.

The modeled sediment yield from each of the three sub-basins within the Winona Lake watershed is shown in Figure 16. This figure shows that the sediment yield from the Peterson Ditch sub-basin exceeded that of the Wyland Ditch sub-basin by a substantial margin, 100 tons. The amount of sediment produced by the Keefer Evans sub-basin was comparatively small; 14% of the Peterson Ditch sub-basin yield, and 18% of the Wyland Ditch sub-basin yield.

Cell erosion figures for the 2-year, 24-hour storm ranged from no sediment production to 4.53 tons/acre. Cells with little or no erosion were those areas consisting of water, wetlands, or peat/clay soils. The highest rate of erosion was found in cell #438. This cell is located in the extreme southern tip of the watershed. The center of this cell is approximately 1.2 miles northeast of Packerton. The cell is bisected by Peterson Ditch. The dominant soil type in this cell was classified as Miami loam, a soil with a high erodibility factor. The land use was 35% row crop agriculture and 44% forested. The land slope, however, was high at 14.5%. The high rate of erosion in this cell can be attributed to a combination of both a high land slope and soil erodibility factor. Cells #152, #285, and #334 all had erosion rates in excess of 3.5 tons/acre. The land use within these cells was predominantly row-crop agriculture. Soils in these areas are mostly loams, and are easily eroded. The land slopes of these cells were in excess of 6% (a relatively large slope). Cell #152 is just south of 350 South Road and mostly east of 500 East Road. It is bisected by Wyland Ditch. Cell #285 is located approximately 2000 feet due west of Sherburn Lake. Cell #334 is situated along 400 East Road between 500 and 600 South Roads. Table 19 summarizes the physical characteristics of these cells.

Nutrient Loading

The AGNPS model supplied estimates for both soluble and sediment-bound nitrogen and phosphorus concentrations (nutrients) in runoff from the watershed. Soluble forms of both nutrients are readily available to aquatic vegetation and phytoplankton, whereas sediment-bound fractions are less likely to have an immediate effect on plant growth and the overall productivity of the lake. Maps showing the cells that contributed a disproportionately greater amount of nutrients during the modeled storm are contained in the following sections. Figures showing nutrient loading for each of the three sub-basins of the watershed are also presented.

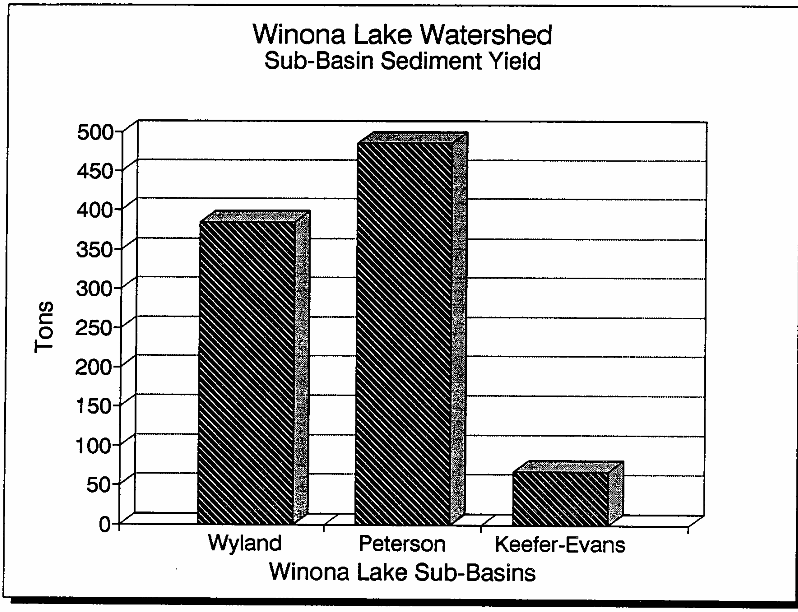


Figure 16. Modeled sediment yield from the Winona Lake sub-basins.

Nitrogen Loading

Using cumulative data generated by the AGNPS model for those cells bordering Winona Lake, it was possible to calculate the total nitrogen (i.e., soluble N and sediment-bound N) loading during the design storm. Total nitrogen loading was 14.43 tons. Approximately 81% of this amount, 11.66 tons was in the form of soluble nitrogen. The much larger percentage of soluble nitrogen can be attributed to the agricultural land use in the watershed. Burwell (1975) reported that surface water runoff concentrations of total nitrogen from continuous corn production may reach as high as 131 mg/L (Burwell et al., 1975).

Figure 17 shows the results of soluble nitrogen loading in the Winona Lake watershed. Soluble nitrogen generated within individual cells ranged from no production to 8.54 pounds/acre. The highest value was observed in cell #449, a primarily row crop area located about one mile east of Packerton, just south of 800 South Road. Cell #71, #113, #210, #337-300, #337-400, and #430 all generated soluble nitrogen levels in excess of 6.00 pounds/acre. Of the seven cells with the highest soluble nitrogen production, five were predominantly clay/muck soils that were heavily farmed. These soils are characterized by high water tables and low water infiltration rates. Six of these cells had more than 80% of their area utilized for row crop agriculture.

Sediment-bound nitrogen generated in individual cells (Figure 18) ranged from 0.00 pounds/acre to 10.6 pounds/acre. The highest value was observed in cell #438, a cell that is 90% row crop agriculture, located just south of 350 South Road and mostly east of 500 East Road. Most of this load can be explained by the high sediment erosion rate within this cell (3.68 tons/acre). Other characteristics of this cell are described in Table 19. Seven other cells generated sediment bound nitrogen at a rate greater than 8.00 pounds/acre (8.96 kg/ha). All of these cells were predominantly row crop agricultural areas and had high sediment erosion rates. These cells are: #285, #308, #313, #334, #335, #361, and #402.

Nitrogen inputs for the three sub-basins in the watershed are shown in Figure 19. In contrast to the per acre loading rates shown in the preceding maps, this figure shows the total yield of both soluble and sediment-bound nitrogen to the lake during the modeled storm. Inputs from Peterson Ditch exceeded Wyland Ditch. On a per acre basis, nitrogen inputs from the Keefer-Evans sub-basin were similar to both Peterson and Wyland sub-basins, however the total input to the lake was less than 20% of either of the two larger sub-watersheds. In all three sub-basins, soluble nitrogen exceeded the sediment-bound fraction by a substantial margin.

Phosphorus Loading

The total phosphorus loading to Winona Lake during the modeled storm was 3.71 tons. Of this amount, 2.32 tons (62.6%) was in the soluble form. As was the case with total nitrogen, runoff from agricultural land is the most likely source of soluble phosphorus.

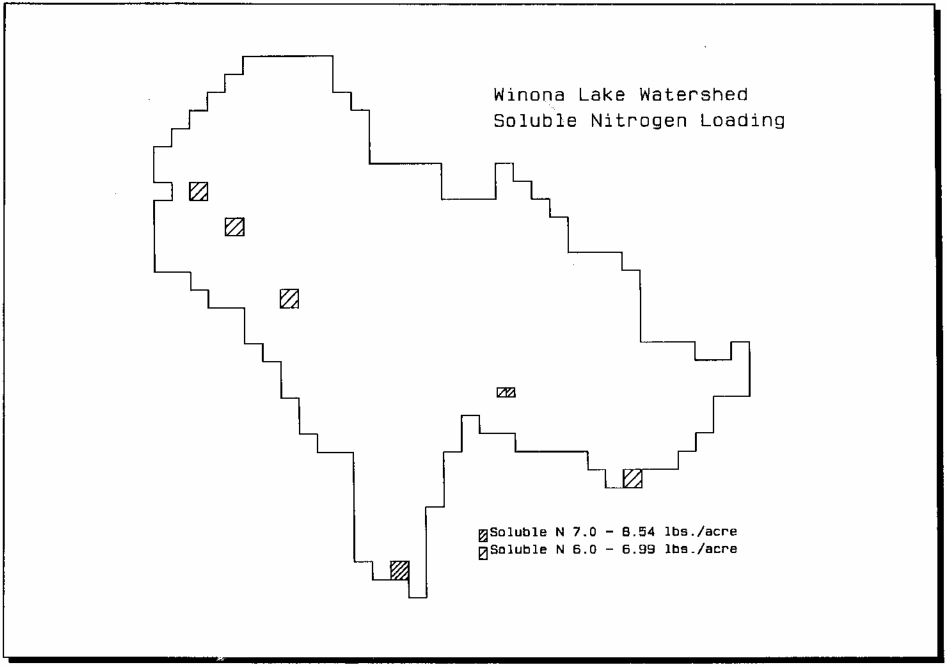


Figure 17. Modeled soluble nitrogen loading for the Winona Lake watershed.

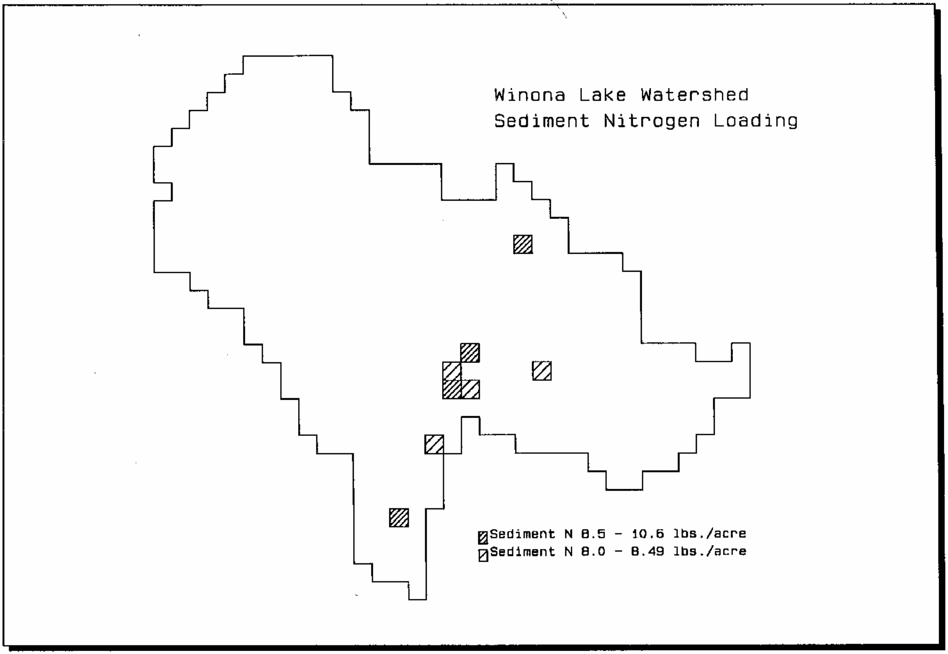


Figure 18. Modeled sediment nitrogen loading for the Winona Lake watershed.

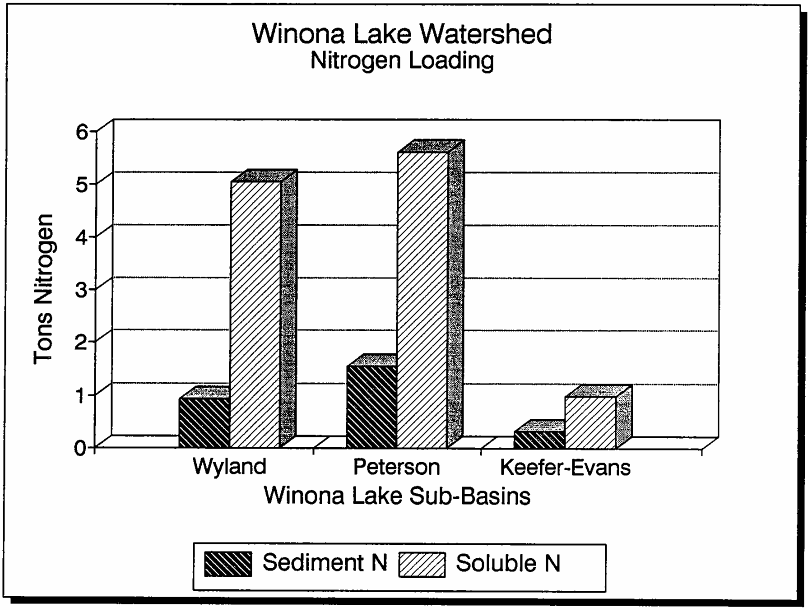


Figure 19. Modeled nitrogen loading for the Winona Lake sub-basins.

Figure 20 shows the cells contributing disproportionately greater amounts of soluble phosphorus. Values for individual cells ranged from 0.00 pounds/acre to 1.81 pounds/acre. The maximum input was from cell #449, a cell that also had the highest soluble nitrogen production. Cell #449 is located about 1 mile east of Packerton and 500 feet south of 800 South Road. Row crops represented over 90% of the land use within this cell. The dominant soil was a muck/clay type with a high water table and low water infiltration rates. Cell #337-400 (southeast quadrant of cell #337) produced soluble phosphorus at a rate of 1.55 pounds/acre (1.74 kg/ha). This cell is located on the southeast shore of Seller's Lake. Land use in this cell is approximately 61% residential and 25% row crop. The soil type is also muck/clay.

Within cell sediment-bound phosphorus ranged from 0.0 pounds/acre to 5.30 pounds/acre. Cell #438 generated the highest value (Figure 21). This area also had the highest level of cell erosion (4.53 tons/acre). As was mentioned in the previous discussion on cell erosion, this cell had a high land slope (14.5%). The volume of sediment generated by this cell is responsible for its high sediment bound phosphorus production. Eight cells in the watershed generated more than 4.00 pounds/acre of sediment-bound phosphorus. These cells were: #152, #285, #308, #313, #334, #335, #361, and #402. Further characteristics of these cells are summarized in Table 19.

A comparison of phosphorus loading from each of the three sub-basins of the watershed is shown in Figure 22. Inputs from Peterson Ditch (1.89 tons) accounted for over 50% of the total phosphorus inputs from the watershed. Wyland Ditch added approximately 40% of the total amount of phosphorus entering Winona Lake. A relatively small amount of phosphorus entered the lake from the Keefer-Evans sub-basin. The soluble fraction exceeded the sediment-bound form of phosphorus in all three of these drainages.

Runoff

Cells within the watershed with runoff values of 1.44 inches or more during the modeled storm are shown in Figure 23. This value represents 80% of the peak runoff (1.79 inches) that was predicted during the modeled storm. Cell #216-400 had the maximum runoff in the watershed. This is the southeast corner of a 40 acre cell that consists of a combination of wetland and row crop land use. The water table in this cell is relatively high and the soils are probably in a saturated condition, particularly during the spring. Land use in other cells with high runoff also was characterized by both row crop and wetland land use types.

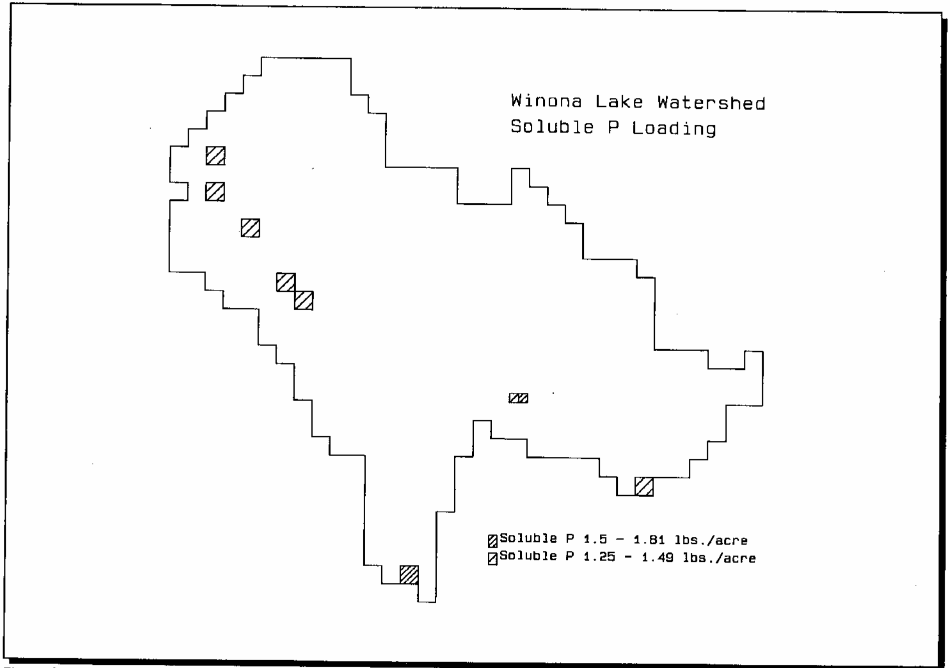


Figure 20. Modeled soluble phosphorus loading for the Winona Lake watershed.

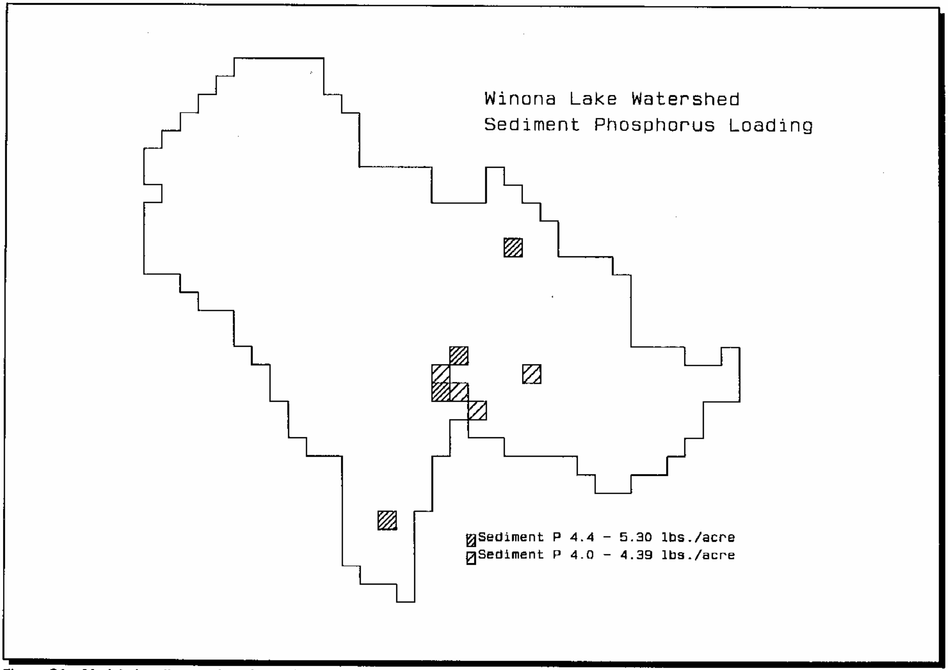


Figure 21. Modeled sediment phosphorus loading for the Winona Lake watershed.

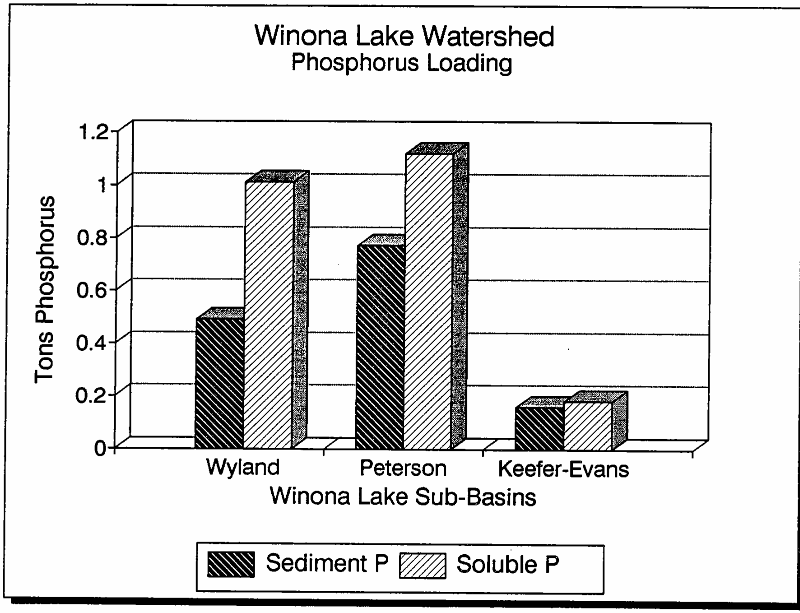


Figure 22. Modeled phosphorus loading for the Winona Lake sub-basins.

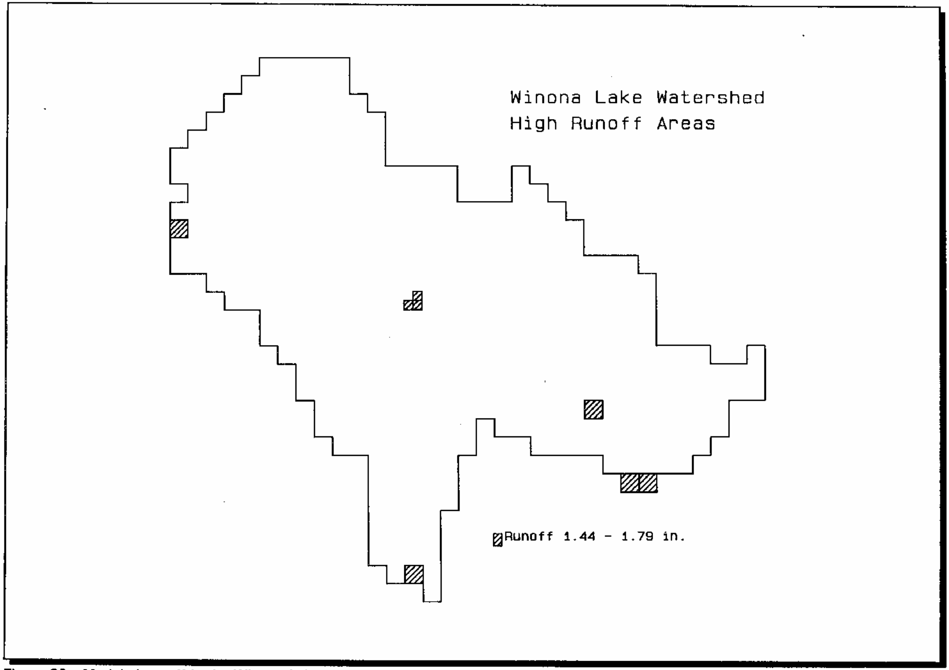


Figure 23. Modeled runoff in the Winona Lake watershed.

SECTION 5. SOURCES OF SEDIMENTS AND NUTRIENTS

Based on the results of the AGNPS modeling, storm sampling, land use analysis, and visual observations, areas considered to be major sources of sediments and nutrients were identified. Although the major issue prompting both the Feasibility and Design components of this study was the shoaling in the lake at the Wyland Ditch inflow, it appears that inputs from Peterson Ditch are also significant. The storm samples collected at this site, and the results of the modeling and historical information all point to the Peterson Ditch sub-basin as an important source of nutrients and sediments to Winona Lake. However, the yield of sediment and nutrients to a tributary or other water source varies greatly from storm to storm. Even within the same stream, the concentration of suspended solids can vary by a factor of 10 for a given flow rate. Given this variability, areas in addition to those identified during this study as trouble spots may exist. The following sections outline the principal sources of sediments and nutrients in the watershed.

5.1 SEDIMENTS

Sediment inputs to the lake are generated by upland sources in the watershed. Based on the results of the AGNPS modeling, the majority of the sediment inputs to the watershed originate from areas dominated by row crop agriculture; particularly where there is a combination of intensive-till farming, hilly slopes, and erodible soil types. These combinations occur within the Winona Lake watershed at the AGNPS cells listed in Table 19. Sediments can also be produced within the stream channels themselves if the velocity is high enough to dislodge material from the streambed or bank. Cells that contain stream channels, as well as a high percentage of row crop agriculture, should be priorities for BMP implementation.

Almost all of the sediment reaching Winona Lake arrives via either Wyland Ditch or Peterson Ditch. The pond in the Keefer-Evans sub-watershed just upstream of the mouth of the lake functions as an effective sediment trap for this tributary. Both the AGNPS results and the stormflow samples indicate that Keefer-Evans Ditch supplies a small percentage of the total sediment load to the lake. In terms of the relative contributions of the two major tributaries, the modeling results showed greater a greater contribution of sediment from Peterson Ditch than from Wyland Ditch. However, the TSS level in the Wyland Ditch storm sample was over twice that of the Peterson Ditch sample. This "discrepancy" can be attributed to two factors:

- The AGNPS modeling results were based on a two year, 24 hour event; storm samples were collected during a storm of much greater frequency.
- The modeling results incorporated inputs from the entire storm, while the sampling results are only for a single moment in time during the event. Actual concentrations vary considerably throughout a given storm.

Despite the differences between the modeling and stormflow results, the conclusion that must be drawn is that both Peterson and Wyland Ditches supply sediment to the lake. However, the bank stability analysis suggests that sediment from Wyland Ditch is primarily a result of watershed inputs. Sediment entering the lake from Peterson Ditch may be composed in large part of material from the ditch itself.

5.2 NUTRIENTS

Inputs of nitrogen and phosphorus to the lake come primarily from watershed inputs, i.e., runoff from upland areas in the watershed and/or the urban and residential areas surrounding the lake. Areas of higher nutrient contribution in the watershed were identified using the AGNPS model. The following is a discussion of other potential sources of nutrients to the lake. These include:

- urban runoff
- residential fertilizers
- waterfowl
- septic systems

5.2.1 Urban Runoff

Discussion with officials at the Kosciusko County Health Department indicates that urban runoff is a significant problem facing Winona Lake. Several storm drains enter the lake, and the industrial park at the north end of the lake has been a concern for many years. Four National Pollutant Discharge Elimination System (NPDES) permits are in effect for Dalton Foundry, Gatke, Warsaw Plating, and the American Associated Milk Producers. The permits are for the discharge of non-contact cooling water, i.e., water that does not come into contact with the manufacturing process. However, visible sheens on the water and discharges of whey have been observed in this area of the lake on several occasions. Potential contamination from Warsaw Chemical is also of concern. Organic compounds from this facility may be reaching the lake through groundwater inputs, however detecting this is difficult because the chemicals volatilize at the surface. Nutrient contributions from these point sources are likely to be less important than other constituents, such as metals and organic compounds. However, from the perspective of the overall health of the lake, it is clear that point sources and urban runoff must be considered significant factors affecting water quality.

5.2.2 Septic Systems

The majority of the homes along the shore of the lake are on the Warsaw city sewer system, however a section of the shoreline on the western side of the lake is still on septic systems. Problems with these systems have been reported. An extension of the sewer line to this area is planned for 1991.

5.2.3 Fertilizers

Fertilizers from lakeshore residences and the Stonehenge Golf Course are potential sources of nutrients to Winona Lake. The storm sample results indicate that a storm of moderate intensity produces high concentrations of nitrogen and phosphorus, far greater than the concentrations found in the lake. It is difficult to separate agricultural from residential sources of nutrients without a large number of sampling locations, however nitrate levels in Keefer-Evans Ditch were higher than Wyland Ditch. Differences in runoff volume undoubtedly influenced the storm samples, however land use also plays a major role. This area of the watershed is largely residential, and it is likely that lawn fertilizers are a significant contributor of nitrogen. In the Wyland Ditch watershed, the total phosphorus level in the storm sample was approximately 30 times greater than the other two tributaries. Again, this is due in part to differences in runoff volume, however fertilizer application to golf courses is known to increase nutrient concentrations in runoff. Inputs from Stonehenge Golf Course could be a significant source of nutrients to Winona Lake.

5.2.4 Waterfowl

Large numbers of ducks and geese were seen during each visit to the lake by IS&T. In December of 1989, while the lake was under ice-cover, there was a large number of birds utilizing the open water area at the north end of the lake. Heated discharges in this area maintain open water year-round. No estimates can be made concerning the nutrient contribution of waterfowl to Winona Lake, however this is a significant problem for cities in other parts of the Midwest.

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SECTION 6. SEDIMENT AND NUTRIENT CONTROL

Based on the results of the AGNPS modeling, the main source of watershed inputs of sediments and nutrients to Winona Lake is via Wyland and Peterson Ditches. The two tributaries drain primarily agricultural lands to the south and east of the lake. Although the AGNPS model did identify problem areas within the watershed, sources of the problems are much more difficult to identify. Agricultural activities in the upland areas, and fertilizer and animal waste runoff are all likely to impact the lake in varying degrees. The AGNPS results point to watershed inputs as the primary source of nutrient enrichment to the lake. Advancing eutrophication in Winona Lake can be slowed considerably through the widespread application of best management practices (BMP's) within the watershed. The following section is a discussion of the types of BMP's that would be expected to have the greatest role in reducing nutrient concentrations and sediment inputs to the lake and receiving streams. Section 6.1 focuses on erosion control techniques that will reduce both nutrient and sediment transport to streams. The techniques described are primarily aimed at reducing loading from agricultural areas, however urban erosion control is also discussed. This section (6.1.2) is especially applicable to areas of exposed earth along the lower reaches of Wyland Ditch, particularly the area disturbed by the sewer line construction in 1988. Section 6.2 provides an overview of BMP's for nutrient reduction specific to agricultural areas. This section also includes recommended maintenance procedures applicable to the park area near the lake. Section 6.3 discusses applicable in-lake restoration techniques.

6.1 EROSION CONTROL

This section provides an overview of agricultural BMP's that have been developed for erosion control on cropland, pastures, and streambanks. Within the Winona Lake watershed, erosion control is especially important on lands adjacent to or near tributaries streams. The AGNPS model showed high sediment yield along the length of both Peterson and Wyland Ditches. The sewer line construction adjacent to Wyland Ditch is a good example of where construction was conducted with insufficient erosion control measures.

Although not classified specifically as lake restoration techniques, erosion control practices maintain productivity on the land, reduce costs of fertilizers and pesticides, and ultimately benefit receiving streams and lakes. The Soil Conservation Service has published design criteria for a variety of BMP's, including those discussed below. This agency has and will continue to provide guidance to individual farmers and land owners in selection and implementation of BMP's. The following summary is drawn from a manual developed by the U.S. EPA, in conjunction with the North American Lake Management Society (NALMS), entitled The Lake and Reservoir Restoration Guidance Manual, published in 1988. Other sources of information include technical publications received through extension services and the SCS.

6.1.1 Agricultural Erosion Control

Conservation Tillage

Erosion in agricultural areas of the watershed can be significantly reduced by conservation tillage practices. The objective of this type of BMP is to protect soil from wind and water erosion by increasing the amount of crop residue. No till farming, where the topsoil is left essentially undisturbed year round, and minimum tillage are forms of this BMP. The effectiveness of these practices in reducing sediment loss and runoff is considered fair to excellent, depending on the degree of tillage reduction (USEPA, 1988). Phosphorus in runoff can be greatly reduced with conservation tillage, however nitrogen concentrations are largely unaffected. In fact, total nitrogen and herbicide concentrations may increase in groundwater as a result of no till practices, a potential negative side effect. Fertilizer management and integrated pesticide management should accompany conservation tillage practices.

Contour Farming/Stripcropping

Contour plowing and contour stripcropping are effective in reducing soil loss on farm land with a 2-8 percent, and 8-15 percent slope, respectively. Both practices require plowing along the natural contours. In stripcropping, grasses or other close growing crops are planted between row crops, such as corn or soybeans.

Streamside Management/Buffer Strips

Vegetation planted between a stream and plowed field (a buffer strip) is extremely effective in reducing both nutrient and sediment inputs, and in protecting riparian habitat. This is a very cost effective practice. Once established a buffer strip will maintain itself indefinitely. Parameters that determine the effectiveness of filter strips include filter width, slope, vegetation type, and application rate of fertilizers.

Other Erosion Control Practices

Management of pasture lands to prevent overgrazing, thereby reducing soil compaction and runoff, is important in an overall sedimentation control plan. Stream banks should be fenced to prevent access to cattle and destruction of soft banks. Crop rotation, terracing, and soil stabilization are also effective in reducing sediment inputs to streams.

6.1.2 Urban/Residential Erosion Control

Control of erosion due to development or construction activities must be a component of a watershed wide approach to reduce sedimentation in Winona Lake. Factors that influence the type and amount of erosion include the nature and extent of vegetative cover, topography; and the frequency, and intensity of rainfall events.

Vegetative cover plays a critical role in controlling erosion by absorbing the impact of falling rain, holding soils together, increasing the retention capacity of soils, and slowing runoff velocity. Evapotranspiration by plant cover also aids in reducing erosion by removing water from soils between rainfall events.

Topographic characteristics (i.e., slope, size, and shape) of the drainage basin have a strong influence on the amount and rate of runoff. Changes to site topography resulting from development can have a significant impact on the quantity of runoff, and therefore sediment, that is generated.

The characteristics of surface and subsurface soils are fundamental to the resistance of soils to erosive forces, and to the nature of the sediment that results from erosion. Soils with high sand and silt content are normally the most highly erodible. Increasing organic and clay content result in decreased erodibility, however these soils are more easily transported.

In general, the following practices may be applied to control erosion due to land development activities within the Winona Lake watershed. These practices are not presented in detail. An excellent source of further information specific to Indiana is the Hoosier Heartland Resource Conservation and Development Council's Urban Development and Planning Guide (HHRCDC, 1985). This document can be purchased from the HHRDC for $15.00. Orders may be sent to: Hoosier Heartland RC&D, 5995 Lakeside Blvd., Suite B, Indianapolis, IN, 46278 (317-290-3250). In addition to this document, a publication entitled "A Model Ordinance for Erosion Control on Sites With Land Disturbing Activities" provides guidelines for erosion control in a format that is readily adoptable by Counties or local government. The document is published by the Highway Extension and Research Project for Indiana Counties and Cities (HERPICC, 1989), and is included with this report as an Attachment.

Phased Construction: Phasing construction activities minimizes the extent of land disrupted at one time, reducing the sediment load to a receiving stream or lake during a given storm event. If multiple structures are to be built over an extended period, the entire area slated for development may not have to be cleared at once.

Road Stabilization: Several practices are available to minimize erosion and sediment transport due to traffic in construction areas. These include stabilization of freshly graded road surfaces with gravel and installation of gravel pads at entrances to construction sites. The latter serve to reduce the amount of sediment carried off-site on tires of construction vehicles.

Sediment Barriers: Various types of barriers may be placed in the path of runoff to detain sediment and decrease flow velocities. These barriers, consisting of hay or geotextile filter fabric, are placed across or at the toe of slopes. Sediment barriers are also effective in protecting storm drain inlets from construction site runoff.

Sediment Traps and Basins: Temporary basins may be constructed to contain flows long enough for sediment to settle out. These basins are characteristically simple, often consisting of a small pond formed by an earthen dike, with a gravel lined outlet.

Establishment of Vegetative Cover: Planting of fast growing grasses and other plants provides a means for quickly stabilizing disturbed areas. The choice of plant type will depend on the intended permanency of the cover. Mulching with straw and other fibrous materials will aid in establishment of protective vegetation. This in itself will reduce erosion and runoff on disturbed areas.

Erosion/Sediment Control Plan: For future developments in the Winona Lake Watershed, an erosion and sediment control plan should be developed to address the potential problems resulting from the particular activity. The plan should clearly present the anticipated erosion and sedimentation problems that are likely to result, and the measures that will be taken to mitigate them. Both narrative and graphical sections should be included. The narrative section should include the following:

- Brief description of the project
- Existing conditions (physical features, slope, etc.)
- Description of adjacent areas that may be impacted
- Summary of soil characteristics
- Identification of problem areas (high slope, erodible soils, etc.)
- Erosion and sediment control measures to be used
- Description of post construction stabilization and practices, including measures to control storm water runoff
- Storm water runoff concerns and impacts
- Inspection and maintenance schedules planned
- Calculations used in design of basins, waterways, and other structural controls.

Graphical materials in the site plan should provide the necessary maps and related materials, including:

- Vicinity map showing site location
- Current elevation contours
- Existing vegetation types and locations
- Soils
- Critical erosion areas
- Existing drainage patterns
- Proposed contours after grading
- Limits of clearing and grading

- Location of erosion and sediment control practices
- Detailed drawings of structural practices to be used

The final plan should be subject to approval of a county or local planning board or similar group, and should provide comprehensive documentation of the erosion and sediment control strategies to be applied in the development of the site.

6.2 WATERSHED NUTRIENT REDUCTION

In addition to causing nuisance algae and other water quality problems in the lake, excessive nutrient loading can result in groundwater contamination and human health effects. Erosion control measures will decrease sediment bound nutrient loading, however a reduction in the transfer of soluble fractions of phosphorus, and particularly nitrogen must also be a management priority. Animal wastes and fertilizers are two key sources of soluble nutrients in the watershed. The section below focuses on BMP's designed specifically to reduce soluble inputs. Animal wastes from feedlots and confinement areas, application of animal manures as fertilizers, and commercial fertilizers themselves are primary sources of soluble nitrogen and phosphorus. BMP's for pasture management and stream protection are also described.

6.2.1 Animal Production and Keeping

The need for confinement of animals in feed lots or holding facilities, as opposed to open pastures, results in highly concentrated runoff. Summaries of several BMP's that have been designed to address problems associated with confinement areas are presented below.

Roofing: On the average, the Winona Lake watershed receives over three feet of rainfall per year. This means that for each acre of open confinement area, close to a million gallons of contaminated water are generated on an annual basis. Washdown water may equal this amount. Roofing confinement areas allows separation of clean runoff from contaminated slab runoff. Roof gutters and a water collection system greatly reduce the amount of water that must be treated.

Location: The amount of pollutants entering a stream decreases with distance from the source. The distance where zero pollution enters a waterway has been estimated to be 98 to 393 feet, depending on soil characteristics, grass type, and density of cover (Novotny and Chesters, 1981). Confinement areas should be built up and graded away from a ditch or stream. Animals should be fenced no closer than the top of the grade. The ditch slope should have a grass cover, and the runoff from the storage facility should be retained.

Washdown Water: BMP's for the use of washdown water focus on recycling and reduction in the quantity of water used. Substituting higher water pressure for volume and scraping manure prior to hosing minimizes water usage.

Manure Storage Lagoons: Farms with a limited capacity for liquid manure storage must frequently spread the lagoon contents on pasture land to prevent overflow. This often results in ponding of the liquid waste during periods when the ground is saturated, e.g., following snowmelt in the spring. Manure applied under these conditions is likely to flow off of the field and into a waterway. Installation of a solids separator ahead of the lagoon increases the capacity of the lagoon and lengthens the period between cleaning. In addition, odor problems are reduced.

6.2.2 Manure Application to Pastures

Although no data were collected for the Winona Lake watershed, it is probable that a large percentage of manure that is produced from animal production is returned to the land. There is general agreement that manure can and should be used in crop production to increase yields and fertility. However, water quality degradation will occur without proper management of manure application. Proper timing of application (i.e., during non-saturated conditions), application to land with minimal slope, addition of manure in quantities equal to crop requirements, and avoidance of soil compaction during the application process will minimize problems due to manure application.

6.2.3 Fertilizer Management

Application of fertilizers in quantities equal to crop needs will greatly reduce nutrient enrichment of aquatic resources due to agricultural operations. Reducing the loss of nutrients to the groundwater or air is dependent on proper soil testing, and establishment of realistic yield goals. Knowledge of the contribution that legumes, manure, and crop rotation make to soil nitrogen and phosphorus levels is critical to determining proper application rates.

Over application of nitrogen has been recognized as a significant problem in agricultural areas throughout the country. Although some degree of over-application is necessary given significantly less than 100% uptake efficiencies, current research on this problem points to a lack of consideration of alternative sources of nitrogen, such as manure or alfalfa, in calculating the quantity of fertilizer necessary for a given yield (Granatstein, 1988). Nitrate in soils in excess of crop requirements results in groundwater contamination, as well as increasing eutrophication of surface waters. Nitrogen "credits", i.e., a reduction in the amount of nitrogen necessary due to carryover from previous crops (legumes) or to crop rotation result in both cost benefits to farmers and improved water quality. Examples of nitrogen credits, in terms of pounds/acre N for previous legume crops, are shown in Table 20. This information is taken from material published in a University of Wisconsin Extension Bulletin (Granatstein, 1988). The Kosciusko County SCS District Conservationist, Sam St. Clair, can provide additional information on nitrogen management.

Phosphorus is not as mobile a nutrient as nitrogen, and will tend to remain in the soil for longer periods of time. Erosion will reduce soil phosphorus levels, however in many cases, phosphorus levels will have

Table 20. Nitrogen credits for previous legume crops (from Granatstein, 1988).

CROP	N CREDIT
Forages	
Alfalfa	40 lb. N/ac. plus 1 lb. N/ac. for each percent legume in stand.
Red Clover	Use 80% of alfalfa credit.
Soybeans	1 lb. N/ac. for each bu/ac. of beans harvested up to a maximum credit of 40 lb. N/ac.
Green Manure Crops	
Sweet Clover	80-120 lb. N/ac.
Alfalfa	6-100 lb. N/ac.
Red Clover	50-80 lb. N/ac.
Vegetable Crops	
Peas, snapbeans, limabeans	10-20 lb. N/ac.

built up over the years, and continued, or "maintenance applications", may not be economically justified (Granatstein, 1988). As with nitrogen, the rate of application of commercial phosphorus fertilizers can be reduced or even eliminated when fertility credits from manure are accounted for. A program of regular soil testing combined with maintenance of proper soil pH is essential to avoid over application of phosphorus.

Timing of application is also a key factor in reducing the quantity of fertilizers that reach ground or surface waters. In general, application in the fall results in significant runoff and loss during the non-growing season. Spring pre-plant application is recommended.

6.2.4 Septic Systems

Homes on septic systems within the watershed, and more importantly, on the lakeshore, may be a source of nutrients. No data were collected during the Feasibility Study that indicated this, however a detailed septic system survey was beyond the scope of the project. The following paragraphs offer general guidance on installation, use, and maintenance of septic systems.

Proper Location: The features governing appropriate placement of septic systems include proper soils and adequate buffer distances between the drain field and sensitive areas. Information is available from both the SCS and USGS concerning the suitability of various soils and geologies for drain field construction. These agencies should be consulted prior to installing any new system. The Indiana Department of Environmental Management should also be contacted to determine the most recent limitations concerning minimum distance of the drain field from drinking supplies, lakes, drainage ditches, etc.

Regular Inspection and Maintenance: A septic tank should be inspected at least once per year to assess the rate of solids accumulation. If these materials build up, they will be transferred with the waste to the drain field, resulting in clogged soil pores. This condition results in a reduction of permeability, and eventually construction of a new drain field. Septic system maintenance should involve inspection of "Tee-joints" and distribution boxes, since these parts are especially prone to shifting that can lead to uneven dispersal of waste water into the drain field. Material removed from the tank should be discharged at a treatment plant. Periodic inspection and pumping will avoid this expense.

Drain Field Protection: Trees should not be allowed to grow on top of the drain field. Tree roots can penetrate the field, diminishing its efficiency. Vehicular traffic should also be prevented, since this will cause compaction of the leach field soils.

Proper Use: Solids, greases, or toxic materials should not be disposed of in septic systems. Solids, such as paper towels, disposable diapers, add to the overall load of the system, decreasing efficiency and increasing maintenance costs. Fats, oils, and greases can solidify in the system and create blockages. Toxic materials (e.g., paints, motor oil, pesticides) are not decomposed by septic systems and can leach out into groundwater, contaminating wells and eventually reaching lakes and streams. In addition, these materials can kill the beneficial bacteria responsible for decomposing normal septic system wastes.

Additives: Authorities agree that under most circumstances, chemical and biological additives are not needed to accelerate decomposition in the septic field. Under extreme use situations however, these additives may be helpful. Caution must be observed when using these products since some additives will actually inhibit decomposition. Products containing more than one percent of the following chemicals should not be used:

- **Halogenated hydrocarbons:** trichloroethane, trichloroethylene, methylene chloride, halogenated benzenes, carbon tetrachloride;
- **Aromatic hydrocarbons:** benzene, toluene, naphthalene;
- **Phenol derivatives:** trichlorophenol, pentachlorophenol, acrolein, acrylonitrile, benzidine.

A good reference with information on septic system design and maintenance is found in Perkins (89).

6.2.5 Park and Lawn Maintenance

The following paragraphs provide a summary of maintenance procedures to reduce nutrient inputs to Winona Lake from surrounding lawns and park area. The following "common sense" procedures will minimize nutrient concentration in runoff from these areas.

Grass and Leaves: Grass clippings should be allowed to remain on the lawn following mowing unless excessive thatch build-up occurs. This will reduce the need for artificial nutrients. In addition, this will have a beneficial effect on the nationwide waste disposal problem, as bagged grass or leaves comprise 15-20% of all substances placed in landfills (Hugo, 1990). Raked leaves should not be disposed in or near the lake or its tributaries. Instead, they should be bagged and transported to a compost area away from any water flow path. If a compost area is used, runoff should not be allowed to reach the lake or tributaries.

Trash Receptacles: The number of trash cans and dumpsters should be sufficient to handle all trash deposited between collections. The containers should be cleaned with plain water directed from a spray nozzle. Disinfectants should be used sparingly and not allowed to drain onto the ground. Rinse water containing disinfectant must be properly disposed of.

Holes should not be drilled in the bottom of trash barrels to afford better drainage. Water percolating through these containers is high in nutrient and bacterial content, and should be avoided. Trash cans should be covered and not left open. Spring-loaded lids are recommended, and open topped drums should be avoided. Rusty receptacles should be replaced promptly. Trash cans should be placed as far as possible from the lake.

Fertilizers and Chemicals: Application of fertilizers should be avoided or minimized. These products will enhance the growth of algae and macrophytes in the lake if they are present in runoff. Application of other chemicals, such as pesticides and herbicides, should be carefully controlled and avoided if possible. Alternatives to chemical treatment should be investigated.

Automobile Traffic: The exhaust from internal combustion engines is high in metal, hydrocarbon, and nutrient content. So called "tailpipe drippings" are a major source of nutrients in urban watersheds. Drains and waterways along roads and parking lots should be situated so as not to channel runoff directly into the lake or its tributaries. Ideally, stormwater runoff should be routed to a treatment facility (or holding pond). If this is not feasible, runoff should be routed across large, vegetated areas prior to being allowed to enter the lake or its tributaries.

Education Centers: Visitors to Winona Lake should be educated on issues surrounding the lake and its care. Broad-based nature exhibits or storyboards on specific problems, such as why fisherman should not clean their catch in or near the lake (entrails can lead to elevated bacteria counts and reduction in dissolved oxygen) would promote understanding of water quality issues.

6.3 IN-LAKE RESTORATION

The problems identified in Winona Lake stem from both nutrient enrichment and sedimentation. Although nutrients may be contributed as a result of near-shore activities, watershed inputs largely determine both in-lake nutrient concentrations and sedimentation rates in Winona Lake. As stated earlier, implementation of the BMP's previously described is considered the most effective strategy to restore the lake. The treatment of problems similar to those experienced in Winona Lake through in-lake techniques has been successful, however in most cases the lakes are smaller or have longer retention times (Cook et al.,1986). The very large volume of Winona Lake (approximately 17,000 acre-feet) make in-lake techniques such as lake aeration and phosphorus inactivation (alum treatment) prohibitively expensive. However, as discussed in Section 9, the results of this study do not point to the need for in-lake measures at this time. Moreover, in-lake techniques, particularly those designed specifically to reduce nutrient concentrations, would be short-lived without corresponding measures in the watershed. These practices, such as no-till farming and animal waste management, will go farthest and be the most cost-effective solutions to long-term improvement in water quality. A combination of watershed BMPs and stream stabilization should be the primary tools to reduce sediment and nutrient levels in Winona Lake.

Recognizing that there may be a need in the future to consider in-lake techniques, the following section describes four treatment methods that are routinely used in lakes and reservoirs. This information is presented for background purposes only.

6.3.1 Aquatic Plant Harvesting

A reduction in internal nutrient loading is an indirect benefit of aquatic plant harvesting. The direct benefits relate primarily to increased recreational use of the lake. However, nutrient removal and protection of the pelagic zone from nutrients released during macrophyte decay may also result from harvesting. If nutrient income is low to moderate and weed density is high, as much as 50 percent of the net annual phosphorus loading could be removed through intensive harvesting (USEPA, 1988). Mechanical harvesting, however, is energy and labor intensive. Additionally, plants may fragment and spread the infestation. It is recommended that floating barrier systems be utilized during harvesting to curtail the spread of buoyant plant fragments, and aid in their collection.

The objective of aquatic plant harvesting is to cut and remove nuisance growths of rooted aquatic plants and associated filamentous algae. The most common means of harvesting is accomplished through the use of a mechanical weed harvester; a maneuverable, low-draft barge designed with one horizontal and two vertical cutter bars, a conveyor to remove cut plants to a holding area on the machine, and another conveyor to rapidly unload plants. Harvesters vary in size and storage capacity, with cutting rates ranging from about 0.2 to 0.6 acres per hour depending on the size of the machine. Disposal of the cut materials is usually not a problem. Because aquatic plants are more than 90 percent water, their dry bulk is comparatively small. Additionally, farmers and lakeshore residents will often use the cut weeds as mulch and fertilizer.

Most harvesting operations are effective at producing a temporary relief from nuisance plants, and in removing organic matter and nutrients. In some cases, however, plant regrowth can be very rapid (days or weeks). Conyers and Cooke (1983) and Cooke and Carlson (1986) found that a slower method of lowering the cutter blade approximately one inch into the soft sediments would produce a season-long control of milfoil by tearing out the plant roots (USEPA, 1988). This harvesting method is only effective when sediments are soft and the length of the cutter bar (usually 5 - 6 ft.) can reach into the mud.

Contract harvesting costs in the Midwest range from $135 to $300 per acre. Costs for a particular project relate directly to machine cost, labor, fuel, insurance, disposal charges, and the amount of machinery downtime (USEPA, 1988). The cost of a mid-sized mechanical harvester is in the neighborhood of $35,000 to $50,000.

6.3.2 Artificial Circulation

Artificial circulation is a lake restoration technique that is designed to eliminate thermal stratification and density barriers by increasing circulation within the lake. This results in oxygenation of bottom waters, improved fisheries habitat, and, in theory, a reduction in nutrient availability by oxidizing formerly anoxic lake sediments. Cowell et al. (1987) evaluated this technique on a Florida lake using a multiple inversion aeration system. Significant reductions in turbidity, pH, alkalinity, total nitrogen, hydrogen sulfide, and iron were found in this study. Secchi disk transparency also increased significantly. This method has also been shown to control blue green algae blooms by shifting the algal community from blue-green dominated to the more desirable green algae dominated. Blue green algae are more buoyant, and thus have a competitive advantage over green algae during stratified conditions (Lorenzen, 1977). Rapid vertical mixing of the water column reduces this advantage. A marked reduction in blue green algae, and a 70% increase in the number of green algae species was demonstrated in the Florida lake mentioned above (Cowell et al., 1987). However, the results of Cowell's study are for a soft water lake, and not directly comparable to the moderate to high alkalinities typical of midwestern lakes. A direct benefit to fisheries in terms of improved habitat quality, and extended habitat area would be the only result that could confidently be expected if such a system were installed in Winona Lake. Although some degree of reduction in internal nutrient release could be expected, the large watershed to lake area ratio would limit the effectiveness of such a system for this objective. Proper sizing of an aeration system, i.e., adequate air flow to completely destratify the lake, is critical to the success of this method.

In practice, an aeration system employs porous ceramic diffusers, similar to large scale aquarium air stones, or perforated plastic pipe to transfer pumped air from the surface to the lake bottom. Reaeration is accomplished through direct transfer within the water column, and, to a greater extent, by the forced movement of bottom waters to the lake surface. Discussion with Clean-Flo, Inc., a Minneapolis based firm specializing in lake aeration, indicates that approximately 150 diffusers would be required to treat Winona Lake at a cost of roughly $300,000.

6.3.3 Phosphorus Precipitation/Inactivation

The terms phosphorus precipitation or inactivation refer to the removal of phosphorus from the water column (precipitation) or the reduction of phosphorus release from the lake sediments (inactivation). These two in-lake restoration techniques both involve the use of aluminum sulfate (alum) to chemically bind and remove phosphorus. The two techniques differ only in the dose applied. In phosphorus precipitation, the aluminum sulfate is added in a quantity sufficient to remove only the phosphorus present in the water column. The alum quickly becomes aluminum hydroxide, which adsorbs and essentially sweeps the water clean of phosphorus. If the alum is added in a sufficiently large dose, inactivation of phosphorus in the sediments of the lake occurs in addition to phosphorus precipitation. The aluminum hydroxide that settles on the bottom of the lake forms a barrier that greatly reduces the transport of phosphorus to the overlying water. This level of treatment has been shown to be highly effective in reducing the water column phosphorus concentration for long periods of time, reducing the phosphorus content of groundwater seeping into the lake, and in bringing about a measurable and lasting improvement in trophic state.

As pointed out in the majority of the literature available on this treatment method, alum treatment should not be conducted unless it is preceded by efforts to reduce phosphorus inputs from the watershed. Estimates in the literature of the period of effectiveness for this treatment, assuming that the dose is sufficient to neutralize the sediments, range from five to 10 years for a single application.

The negative effects of an alum application relate chiefly to the potential toxicity of dissolved aluminum, which is toxic to fish. However, this problem only occurs if the alkalinity in the lake is insufficient to buffer the effects of the alum, which is acidic due to the sulfate ion. Low initial alkalinity that is further reduced by the alum can result in a drop in pH. Dissolved aluminum is present (and therefore toxic) below a pH of 6.0, and becomes the dominant form of aluminum at a pH 5.5 to 5.0. At a pH greater than this (pH 6 to 8) studies have shown that deleterious effects of alum treatment are minimal and short-lived. Documented adverse effects of the treatment include a reduction in species diversity of plankton in treated lakes, and, in laboratory tests, mortality of Chironomid insect larvae. The reduction in species diversity occurred in West Twin Lake, Ohio, and was attributed to the physical effects of the floc that settled on the lake bottom, the change in species diversity from blue-green to green algae, and the increased clarity of the water which may have increased predation on zooplankton by fish (Cook et al., 1986). The laboratory tests that showed mortality of Chironomidae were chronic tests, i.e., conducted over a long period of time. These tests showed that a typically applied dose of alum can cause mortality in a common lake insect larvae in a laboratory situation. The researchers pointed out that in-lake conditions might mitigate the observed effects. Another study of four alum treated lakes in Wisconsin showed no damage to invertebrate populations during several years of monitoring (Cook et al., 1986).

The increased clarity of the water following alum treatment often results in increased plant growth, another potential negative factor. However, this is usually a manageable problem, and may act to improve fish habitat in lakes where frequent algal blooms have kept macrophyte growth to a minimum.

The most common recommendation to managers regarding application of alum is to closely monitor pH during the treatment process, and to cease the treatment if the pH falls below 6.0. For Lake of the Woods, it is anticipated that the alkalinity would be more than sufficient to maintain a pH greater than 6.0 during and following an alum application. Alkalinities reported in the 1982 study ranged from 140 to 165 mg/L $CaCO_3$. However, for proper dose determination, alkalinities in each major strata of the lake, e.g., the 15 to 20 foot contour interval, should be determined prior to the application. In practice, the lake is divided in into several zones, based on depth, and the dose corresponding to the alkalinity of the particular zone is then applied.

The simplest method of alum application is to apply a dry form over the back of a moving boat. However, a slurried form has major advantages, the greatest being more rapid dissolution. This form of alum requires either an on-board pump to slurry the dry alum with lake water, or a specially made barge designed to load and apply liquid alum directly. The later is the most efficient method of treatment.

The success of an alum treatment is defined by decreased algal standing crop (commonly measured by Chla) and a decreased phosphorus concentration following treatment. A monitoring program during and immediately following the application is essential to gage the response of the lake and to provide the data necessary to interpret the changes in water quality.

Costs of alum application are largely dependent on labor costs and method of application. Discussion of costs and dose determination with Sweetwater Consultants, a Pennsylvania based firm specializing in alum application, indicates that for lakes with alkalinities in the range of 150 mg/L $CaCO_3$, a quantity of 500 gallons of slurried aluminum sulfate should be applied per surface acre of the lake to be treated. Most applications do not treat the entire lake, and include roughly the area from 10 feet to the lake bottom. However, assuming that the entire area of Winona Lake was to be treated (562 acres) a quantity of 281,000 gallons of slurried alum would be required. Sweetwater's estimate of the application costs, including the cost of the alum itself, ranges from \$0.80 to \$1.00 per gallon, for a total cost of \$224,800 to \$281,000.

For further information on firms experienced in alum application, and general information on lake management and restoration, the Winona Lake Preservation Society is encouraged to contact and join the

North American Lake Management Society (NALMS). This organization is a nationwide non-profit group dedicated to effective lake management, and can be reached at the following address:

NALMS
c/o University of Florida
Research and Technology Park
One Progress Blvd., Box 27
Alachua, FL 32615
(904) 462-2554

The EPA Lake and Reservoir Restoration Guidance Manual (1990), Monitoring Lake and Reservoir Restoration (1990), and Cook et al. (1986), are excellent sources of information on alum treatment. The latter reference is the most thorough source, and includes detailed information on dose determination.

6.3.4 Dredging

In the absence of widespread watershed controls, i.e., agricultural practices designed to reduce erosion in the watershed, dredging of the mouths of inlet streams or canals is sometimes necessary. However, the costs of dredging are often prohibitive, and the technique itself seldom receives financial assistance under state or federal projects because it is a short-term treatment, and does not address the sedimentation problem at the source, i.e., erosion from upland areas. In most cases, dredging is limited to the stream channel and the portion of the inlet in the immediate vicinity. The only real advantage of dredging is improved access and greater depth, however a reduction in the rate of nutrient release from the sediments may be a secondary benefit. The disadvantages of dredging in most cases outweigh the benefits. In addition to the high cost, there is the requirement for separate disposal areas, excessive turbidity in the immediate vicinity, and the probable need to redredge the same area within several years.

In general, there are two types of dredging commonly used on freshwater lakes: mechanical and hydraulic dredging. Mechanical dredges consist of a dragline or backhoe operated from shore or from a barge platform. The shore based operation is most common, however maneuverability s much greater if the dredge is operated on a barge. Dump trucks are necessary to offload the dredged material for either shore based or barge based mechanical dredging. For the latter, a second barge is necessary to hold the dredge material prior to transfer to a truck for disposal. The primary advantage of mechanical dredging is the high solids content of the dredge material. Disadvantages include excessive turbidity at the dredge site and a relatively slow rate of removal. Costs of mechanical dredging are approximately $5.00 per cubic yard, assuming a relatively short hauling distance, good access to the site for heavy equipment, and no disposal costs, e.g., landfill costs.

Hydraulic dredges are the most common machines used in wet dredging operations. The dredge consists of a cutter head mounted on the end of a suction pipe suspended from a barge. As the cutter head dislodges sediment, the loosened material is sucked into the pipe in the form of a slurry. The slurry pipe extends from the barge to a disposal site, where a settling basin is required to dewater the material. The advantages of hydraulic dredging include relatively high removal rates, high cost efficiencies, and minimum impact on the shoreline. Disadvantages include the need for containment basins for dewatering the dredge material. The latter will often require that several acres of land near the dredge site be utilized for a period of one to two years. Relatively high turbidity, and the need for a suitable pipeline route from the lake to the dewatering basin are also potential problems. Maximum pumping distance with this technique is approximately one mile. Greater distance is possible, however in-line pumps are required which greatly increase the cost of the operation. Costs of hydraulic dredging range between $2 to $3 per cubic yard of material removed. This does not include construction of sedimentation basins.

Based on the above mentioned costs for hydraulic dredging, the cost of dredging approximately 15,000 cubic yards from the Wyland Ditch mouth would be approximately $40,000.00. This is the quantity of material originally calculated for removal during this Feasibility Study. The cost of construction of a containment basin to dewater (dry) the sediments would be approximately equal to the dredging costs, which would result in a total project cost of $70,000 to $80,000.

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SECTION 7. LONG-TERM MONITORING

A long-term water quality and sediment monitoring program would provide a basis for detecting changes in the water quality of Winona Lake. The objective of such a program would be to assess the condition of the lakes, over time, and draw conclusions regarding future changes that may be observed. Additionally, if a decline in water quality should occur, and the causes are not immediately evident, the data collected under this program would provide the level of detail required for a professional lake manager to analyze the situation.

A monitoring program could be implemented for Winona Lake and Little Winona Lake utilizing volunteers from both the Winona Lake Conservation Association as well as land owners in the watershed. A similar volunteer program is currently underway at Shipshewana Lake in LaGrange County, Indiana. This section describes the basic components of a monitoring program that could be conducted by volunteers, with assistance from a local analytical laboratory. The program is described in two parts: data collection and data interpretation.

7.1 DATA COLLECTION

The core of the monitoring program would be the routine collection of water quality data and sediment depth measurements. The collection of storm flow samples from the tributaries to the lake is also recommended, however, this would be a more difficult task given the unpredictability of sampling frequency.

7.1.1 Lake Water Quality

Water quality monitoring should include both in-situ measurements and laboratory analyses of water samples. In-lake measurements and samples should be collected from a single station at the deepest location in each lake. These measurements should be collected on a regular basis, such as the first Monday of each month, and at approximately the same time of day (i.e., early afternoon). In-situ measurements should include Secchi disk transparency, and temperature and dissolved oxygen profiles. The instrumentation required for these measurements may be purchased for between $850 and $1,000.

Water quality samples should be collected at the surface, mid-depth and approximately one foot above the bottom of the lake. Samples should be analyzed for total phosphorus, total nitrogen and chlorophyll a. A suitable Van Dorn-type water sampler may be purchased for approximately $400. Analytical costs will be dependent on the laboratory used; however, given the similarity in costs among most analytical laboratories, the level of quality assurance that the lab uses should be the determining factor in deciding which laboratory to use. The recommended detection limits, and methods of analyses for lake samples are shown in Table 21. Although the lab need not necessarily be involved in the U.S. EPA Contract Laboratory Program (CLP), it should be able to provide a level of quality assurance and quality control

Table 21. Water quality parameters and analytical requirements for lake samples.

Parameter	Detection Limit	Method No. EPA	SM[1]
Total Phosphorus	0.010 mg/L	365.1	424F
Dissolved Reactive Phosphorus	0.010 mg/L	365.1	424F
Ammonia Nitrogen	0.020 mg/L	350.3	
Nitrite + Nitrate Nitrogen	0.050 mg/L	353.3	
Total Kjeldahl Nitrogen	0.050 mg/L	351.2	420B
Total Suspended Solids	1.000 mg/L	160.2	209C
Chlorophyll a	0.100 mg/L		1002G

Chlorophyll a analyses to be corrected for pheophytin.

[1] APHA - *Standard Methods for the Examination of Water and Wastewater*

that meets CLP guidelines.

7.1.2 Tributary Storm Samples

Because sediment and nutrient loading is the primary issue of concern in Winona Lake, a basic program of tributary storm sampling is recommended. In sampling storm runoff there is a compromise between the ideal, which would involve flow-weighted samples collected throughout each storm hydrograph, and the practical constraints of limited funds to support the program. Flow-weighted sampling is very expensive, requiring sophisticated automatic monitoring and control packages, and substantial labor to maintain the equipment. In contrast, grab samples may be collected manually and only require some sort of sampling container. The disadvantage of grab samples is that they only represent a single moment in the storm hydrograph, and pollutant concentrations are known to vary significantly throughout the duration of a storm. However, the consistent collection of many grab samples over a period of time can provide a basis for comparison among tributaries and detection of large changes in loading though time.

Collection of storm flow samples should be at, or just before the peak flow. Sampling locations should include the mouths of all three tributaries into the lake. At a minimum, storm samples should be analyzed for total suspended solids, total phosphorus and total nitrogen.

7.1.3 Sediment Accumulation

This study documented a large accumulation of sediment near the Wyland Ditch mouth over the last 25 years. Water depths in this area in particular, and near the mouth of both ditches should be measured on a quarterly basis to monitor sediment accumulation.

Sediment monitoring stations should be established on transects running perpendicular to the shoreline and along the centerline of each of the two tributaries. Transects should extend into the lake several hundred feet, with stations spaced at approximately 50 foot intervals along each transect. Stations should be located using surveyor's instruments, such as an electronic distance measuring device (EDM), to allow the depth measurements to be taken at the same location each time. At each station, depth to the surface of the sediment should be measured using a surveyor's rod or similar calibrated pole. Lake surface elevation should be recorded for each round of station measurements to ensure that all measurements are referenced to a common horizontal datum. The Kosciusko County Surveyor may be able to assist the Winona Lake Preservation Association in establishing the sediment monitoring program.

7.2 DATA MANAGEMENT

A single individual, or small group of individuals, should be responsible for all data collection and records maintenance to ensure that the monitoring is conducted reliably and consistently. Consistency of technique and analytical methods is essential to minimize random variability in the data and maximize the value of the collected information in detecting changes over time.

Standardized data forms should be developed and used for all field measurements and sample collection. The forms should be simple, but complete, and as easy to use in the field as possible. Both the in-situ data, and the results from the analytical laboratory should be entered into a PC-based database. There are numerous software packages available that provide the necessary features for ease of maintenance, statistical analyses, and graphics.

7.3 DATA INTERPRETATION

The monthly data generated by this program will provide a general characterization of Winona Lake. There are some simple methods for presenting the data that will allow local lake managers to utilize the data and draw some basic conclusions.

Graphic plots of the water quality and sediment data should be maintained as a basic interpretive tool. Water quality time-series data plots can be used to visually detect seasonal trends, long-term trends, and differences in extreme values between years. Fitting a simple linear regression through time-series data will often allow the detection of a long-term increase or decrease in a measured parameter (i.e., Secchi disk transparency or depth to sediment). Such a trend would be revealed by a regression slope that is statistically significantly different from zero.

Water quality parameters may be evaluated in terms of annual statistics. A simple example would be the examination of the average annual Secchi disk transparency along with the range of transparencies observed during the year. A trend of decreasing annual means and minimum transparencies would suggest that either suspended sediment or algae concentrations are increasing. Additionally, the Carlson trophic state index (TSI) could be applied to the monthly water quality data collected on the lake. A more representative trophic state assessment could be obtained by examination of the TSI values observed over a period of time. A good limnological text, such as Wetzel (83) will provide more detailed interpretive guidance than can be provided within the scope of this investigation.

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SECTION 8. SUMMARY

The results of this study indicate that water quality problems in Winona Lake stem from sediment and associated inputs from the watershed. While this is not a "new" finding, the project has provided valuable information concerning the status of the lake, and the problem areas within the Winona Lake watershed. Using the data developed for the AGNPS computer model, the Kosciusko County SCS, County Surveyors office, and others involved in zoning and land planning now have an important watershed management tool that will be useful now and for many years to come. The findings of this study can be summarized as follows:

- Water chemistry and in-situ (in-lake) measurements indicate that Winona Lake is moderately eutrophic. Dissolved oxygen measurements were near zero from a depth of 25 to 80 feet (about 70% of the total depth near the deepest part of the lake). The average water column total phosphorus values (0.020 mg/L) were below the EPA value of 0.025 that defines a eutrophic lake. However, baseflow tributary samples collected in Wyland and Keefer Evans Ditches were more than four times this value.

- Based on the results of the AGNPS modeling, the Wyland and Peterson Ditch watersheds contribute approximately equal amounts of nutrients and sediment to Winona Lake. However, field observations of bank stability indicate that Wyland Ditch is in a relatively stable condition with respect to sediment inputs. In contrast, the lower reaches of Peterson Ditch are unstable, and the banks of this ditch are a current source of sediment to the lake.

- Baseflow nutrient concentrations in Keefer-Evans Ditch were high relative to the other two ditches. Given the small size of this sub-watershed, and the large percentage of residential land use, commercial fertilizers may be an important source of nutrients to this stream.

- Although not addressed specifically during this study, urban runoff is an important influence on lake water quality. Industrial discharges from companies near the north shore of the lake have been and continue to be a subject of concern. This situation is being addressed by IDEM working with industries on the north shore of the lake. In addition, problems due to septic inputs have been cited in the past. While phosphorus from septic inputs is likely to be a small percentage of the total annual phosphorus loading to the lake, it is critical that placement of new systems be in accordance with IDEM guidelines, and that recommended maintenance procedures be followed.

- As discussed in Section 9.2, dredging of Wyland Ditch is not feasible or advisable at this time.

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SECTION 9. RECOMMENDATIONS

The following section outlines recommendations for improvement and management of Winona Lake based on the results of this study. Recommendations based on the results of the Feasibility Study are described in Section 8.1. The findings and recommendations of the study concerning dredging of the Wyland Ditch mouth and stabilization of Peterson Ditch are presented separately in Section 8.2.

9.1 FEASIBILITY STUDY RECOMMENDATIONS

As previously mentioned, water quality in Winona Lake is largely determined by inputs of sediment and associated nutrients from the watershed. Because of this, the majority of the recommendations are aimed at improving the quality of runoff from both the tributaries and the surrounding residential and agricultural areas. In-lake restoration techniques would not be cost effective unless accompanied by upland watershed controls. Efforts should be focused on implementing best management practices on priority areas; those lands that are near or adjacent to Peterson and Wyland Ditches, particularly areas with relatively high slopes. The AGNPS model data set developed during this study can be used to further evaluate problem areas. In addition, it can be used to test the effectiveness of best management practices by hypothetically altering current land use characteristics, re-running the model, and then evaluating changes in nutrient and/or sediment concentrations downstream.

In order of importance to water quality in Winona Lake, an outline of management strategies is presented below:

- Encourage the use of agricultural BMP's, e.g., conservation tillage, contour farming, buffer strips, and animal waste management. The Kosciusko County SWCD District Conservationist, Sam St. Clair, is a valuable source of information on this subject and can assist with implementation. In connection with this recommendation, the Winona Lake Preservation Association should pursue funding for these measures through the Lake Enhancement Program's Lake Watershed Land Treatment Program. This component of the LEP provides cost share assistance to land users for practices that reduce inputs of nutrients and sediments from agricultural sources. Applications for funding are submitted through the local Soil and Water Conservation District for a given project area, e.g., the Peterson Ditch watershed, as opposed to a specific practice.

- Promote measures to reduce the inputs of lawn fertilizers and other pollutants from residential areas, parkland properties, and golf courses adjacent to Winona Lake or its tributaries.

- Implement effective erosion control in residential areas and at construction sites. This can be accomplished with city and/or county ordinances. A model erosion control ordinance has been included in this report as an attachment.

- Harvest aquatic plants that are causing navigational and recreational problems on an as-needed basis. However, do not attempt to eradicate aquatic plants, particularly at the mouths of inlet streams, since they will reduce the nutrient concentration of tributary runoff and improve fish habitat.

- Wetlands in the Winona Lake watershed are a critical resource, and every effort should be made to preserve them. For landowners wishing to restore drained wetland areas, a U.S. Fish and Wildlife Service (USFWS) Program now provides funds and technical resources for wetland restoration. The USFWS office in Bloomington coordinates this program, however the Kosciusko County District Conservationist, Sam St. Clair, is familiar with the program's requirements and has worked with the USFWS on wetland restoration projects in the county.

9.2 WYLAND AND PETERSON DITCHES

9.2.1 Wyland Ditch Dredging

As stated in the proposal submitted by IS&T to the Winona Lake Preservation Association, the original objective of the Design component of this project was to implement the recommendations of the report completed by Dr. Peter Hippensteel (Hippensteel, 1988) that recommended dredging of the Wyland Ditch mouth. As originally outlined, the Design Study was to provide the design and bid-ready documents to contract the dredging project. The following section describes the process undertaken by IS&T to meet this objective.

An evaluation of whether the dredging should be done hydraulically or mechanically was an early step in the design process. Hydraulic dredging, in which the sediment is removed with a suction dredge and pumped to a nearby containment basin, is generally considered the most efficient and least disruptive dredging method (Cook et al., 1986). A containment basin is necessary to drain the sediments, which are pumped as a slurry from the lake bottom. The hydraulic dredge is extremely maneuverable, and can shape the bottom to a smooth contour at a desired slope. Dredging using a clamshell or dragline method (mechanical dredging) requires a crane operated from a stationary position on shore. In contrast to the boat mounted hydraulic dredge that can freely move over the water surface, the area that can be reached with a mechanical dredge is limited by the length of the crane boom (typically 50 to 60 feet), unless the crane is mounted on a barge. In addition, access roads are required to allow the crane to reach the dredge site, and for loading dump trucks with the dredged sediment. Costs per cubic yard for the dredging process itself are usually lower for hydraulic dredging due the much greater efficiency of this process. However, costs associated with construction of a containment basin result in a total cost that is often equal to or greater than that for a mechanical dredging project. Both methods require advance planning to identify sites for containment (hydraulic dredging) or disposal (mechanical dredging) prior to initiating a project.

Based on the size of the area to be dredged (approximately four acres) and the relatively large volume of dredge material (approximately 15,000 cubic yards), it was determined that the project was beyond the capability of mechanical dredging methods, and that this method could not meet the objectives of the project. This was the over-riding factor in the decision to recommend hydraulic dredging, however the method in general has other benefits that weighed in its favor for this particular project. No truck traffic would be required through the Town of Winona Lake, and turbidity in the immediate area would be minimal. In addition, hydraulic dredging would avoid the need for road construction through the park area adjacent to the mouth of the lake for heavy equipment access. Although a site for the containment basin had not been located, discussion with members of the Winona Lake Preservation Association early in the project indicated that property near the lake would likely be available.

The next step in the Design study was to locate a site for construction of a containment basin. The feasibility of two upland sites; the former Boys Club property and a parking area on the Grace College property, and an in-lake alternative were thoroughly examined by IS&T and design engineers from Engineering Technologies, Inc. Unfortunately, none of the alternatives proved acceptable. For reasons discussed below, the conclusion reached concerning dredging of the Wyland Ditch mouth is that it is not feasible or recommended at this time.

For the former Boy's Club Property, located near the southwest shore of the lake, a full design for a dredge disposal basin was developed. Although use of the site was not guaranteed, a decision to grant access to the site by the owners of the property was contingent on the review of actual engineering plans and specifications for construction. The planned earthen basin was to contain approximately 15,000 cubic yards of sediment that was to be hydraulically dredged from the channel and mouth area and pumped to the site, with a capacity of 20,000 cubic yards. The material would "de-water" in the basin over a period of several months, after which it be removed and the basin re-vegetated. At a meeting held in Warsaw that was attended by IS&T, blueprints for the basin were reviewed by one of the owners of the property, an architect involved in construction of homes for the property owners, and a local realtor. Permission to use the site was denied. An area adjacent to the desired location that was a former landfill for the City of Warsaw, also owned by the developers, was suggested as an alternative by the property owner. For a variety of reasons, including potential contamination of the overlying water in the basin that might result, this was not considered an acceptable solution. The plans developed for the former Boys Club Property site are included as Exhibit 1.

Following the evaluation of the former Boy's Club property, an alternative plan was developed that would involve placement of the dredge material in the lake itself. The plan was to pump the material from the Wyland Ditch mouth area to an existing shallow area at the south end of the lake, creating a partially submerged island. The in-lake disposal option was discussed with Indiana DNR and U.S. Fish and

Wildlife biologists, and the U.S. Army Corps of Engineers (Louisville District). The design of the island would have maximized benefits to fisheries and waterfowl by providing a spawning area and small wetland. Initial reaction to the plan by agency biologists and the Corps of Engineers was favorable. A meeting was held in Warsaw to present the alternative to the Winona Lake Preservation Association. Maps were prepared showing plan and cross sectional views of the existing area and the extent of the proposed island. Although some members of the Association expressed support for this alternative, several voiced concern for recreational conflicts that may arise, as well as safety/liability issues if boats were to run aground on the island. Later discussion with Phil Ehrenman indicated that the in-lake option was not acceptable, and that an upland site should be further pursued.

The final upland alternative that was evaluated was the potential use of existing sedimentation basins built within the Grace College parking area. The Town of Winona Lake has constructed and is currently utilizing this area for containment of sediment dredged from the Winona Lake canal. With the assistance of Mr. Ed Purrington, the Town Coordinator for Winona Lake, IS&T staff and ETA engineers have evaluated the suitability of the existing basin for containment of sediment dredged from the mouth of Wyland Ditch. Exhibit 2 is a letter addressing the use of the basin from Mr. Michael Armstrong, the ETA design engineer who has been closely involved in the dredging issue throughout this project. Although the proximity of the site to the Wyland Ditch mouth is very good, it was determined that the existing basin is not suitable for containment of sediment dredged from Wyland Ditch. The following summarizes several factors that led to this conclusion.

- The sediment that is now contained in the basin at Grace College must remain there until a final location for disposal of the material can be located. The composition of the dredged material has required that IDEM approve the disposal location. An acceptable site has not yet been located.

- The containment basin now being used occupies a majority of the area available at this location, and now holds approximately 3,000 cubic yards of sediment. Based on discussion with Mr. Purrington and Grace College officials, additional area is available for construction of a second basin that may be required for completion of the canal dredging. The second basin would be constructed by the Town of Winona Lake in the same manner as the existing basin. If both could ultimately be used for the Wyland Ditch dredging, the combined capacity would be approximately 5,000 cubic yards. Based on bathymetric data collected during this Feasibility Study, the volume of sediment that would be removed from Wyland Ditch is approximately 15,000 cubic yards. The lack of sufficient capacity to contain the entire quantity of dredged material would require a phased dredging operation. While this could be a feasible option, questions concerning the structural integrity of the basins (see below), the probable tripling in mobilization costs, and the increased time that the site will be required all are cause to reject this option.

- In addition to the volume limitations, the structural stability of the existing and proposed basins was questioned. Although stable at this time, there was no employment of engineering techniques that would have been specified by IS&T in conjunction with design engineers from ETA, Inc. Potential failure of the dikes surrounding the sediment was cited in the attached letter shown in Exhibit 2.

The lack of a suitable containment site is the primary reason that dredging of the Wyland Ditch mouth is not currently feasible, as it was originally proposed. Three alternatives are presented as a result of this conclusion:

<u>Alternative</u> <u>A.</u> Reduce the area to be dredged to allow the project to proceed using mechanical dredging methods.

<u>Alternative</u> <u>B.</u> Delay dredging until a suitable site for a containment basin can be located for a hydraulic dredging project.

<u>Alternative</u> <u>C.</u> Eliminate dredging of the Wyland Ditch mouth as a current management objective for Winona Lake.

Based on the findings of the Feasibility component of this study, and on discussion with members of the Winona Lake Preservation Association, Alternative C is recommended. In addition to the current problem of lack of a containment site, this recommendation is based on a comparison of the relative benefits of stabilizing Peterson Ditch versus dredging of the Wyland Ditch mouth, and on comments by several members of the Winona Lake Preservation Association that have seriously questioned the need for the Wyland Ditch project.

Choosing either Alternative A or B would require that further resources be committed to location of disposal areas for Wyland Ditch sediments. Alternative A would require close coordination with the Town of Winona Lake and officials involved in community planning to address the issue of access to the lake if mechanical dredging were employed. Discussion with local firms that do mechanical dredging indicate that a barge-based operation would not be possible, which significantly reduces the area that could be dredged.

Further support of Alternative C results from comparing the relative benefits of dredging Wyland Ditch to work on stabilizing the Peterson Ditch channel. No quantitative cost/benefit analysis was conducted, however it is clear that bank stability in the Peterson Ditch channel is a cause for concern, whereas the Wyland Ditch channel is in a much more stable condition. The delta at the mouth of Wyland Ditch was observed on aerial photos dating back over 40 years, and the extent of the delta appeared to be similar to that of today. It is likely that the rate of sedimentation calculated during this project (1.7 inches per year since 1965) will slow considerably as best management practices become more widely implemented in the watershed. In addition, the material itself is largely composed of sand, and the nutrient contribution from the delta to the lake is likely to be minimal. In fact, the delta may act to filter nutrients entering the lake from the Wyland Ditch sub-basin. The primary benefit of removing the delta would be increased lake depth in this area, however this is not deemed entirely beneficial by some members of the Winona Lake Preservation Association. On the basis of benefit per dollar spent on restoration of Winona Lake, priority should be given to the Peterson Ditch Design and Construction project described below, and to efforts to promote BMP application in the watershed.

9.2.2 Peterson Ditch Stabilization

Based on the findings discussed earlier concerning the instability of the lower reaches of Peterson Ditch, The Winona Lake Preservation Association should apply for funding for a Lake Enhancement Program Design Study on Peterson Ditch. The objective of this study would be to provide the information necessary to construct bank revetments along the lower one and one-half miles of this tributary. This section of Peterson Ditch has extensive bank erosion and mid-channel bars. The design study would involve a topographic survey of this section of the stream, and collection of the following information on the stream channel:

- location of the centerline of the channel
- the height, length, and location of eroding banks
- the path of the deepest part of the channel (thalweg)
- width and depth of the channel
- slope of the water surface
- contours of the first 50 feet of overbank areas adjacent to eroding banks.

Because the topographic survey would be the major component of the Design Study, it could be accomplished at a relatively low cost and with minimal expenditure of labor and materials. The Winona Lake Preservation Association is encouraged to contact Kosciuskco County to request support for the Design Study in the form of technical assistance, primarily the work assocuated with surveying the stream and developing stream cross sections. The County Surveyor, Mr. Richard Kemper, has been very helpful to IS&T throughout this project. In addition to the survey information, the products of the study would include a bid package containing the information necessary to contract construction of stabilization measures. Maps and diagrams detailing the placement of materials and specific requirements for construction would also be products of the Design Study.

Based on the detail provided in the Design Study, the construction phase of the project would involve placement of bank revetments, or reinforcements. Although structural materials, such as riprap or gabions (rock-filled wire baskets) are often used in similar projects, natural materials offer many advantages and are strongly recommended for Peterson Ditch. The term "natural", or native materials implies the use of tree root wads, boulders, and hearty plants such as willows to armor the banks. These materials can be installed with minimal equipment, and provide equal or greater protection at a fraction of the cost. In addition, the natural appearance of the stream is maintained, and the impact of construction itself is minimal. In contrast to the excavation that would be required to reduce the bank slope if riprap were used, native materials can be installed in near vertical banks. This eliminates the need for temporary access roads for heavy equipment, because the work can generally be done using a backhoe mounted on tracks which can move in the stream channel itself. Other benefits include the increase in habitat for fish that is provided by root fans imbedded into the bank.

Discussion with Mr. James Gracie of Brightwater Consultants, Inc. in Baltimore, MD, a firm experienced in streambank stabilization using native materials, indicates that the cost of the Design Study for Peterson Ditch project would be less than $25,000. As a subcontractor to IS&T, Mr. Gracie was responsible for tributary classification and the recommendations concerning bank stabilization. Brightwater Consultants is active in all phases of stream restoration, and it is recommended that this firm be provided an opportunity to be involved in further work on the Winona Lake tributaries.

SECTION 10. PERMITS

Prior to initiating any lake or stream restoration project, the Winona Lake Preservation Association is strongly encouraged to discuss the planned project(s) with the State and Federal agencies responsible for permitting them. The U.S. Army Corps of Engineers, Louisville District, is responsible for administering Section 404 of the Clean Water Act, which governs all activities that involve the discharge of dredged or fill material to waters of the United States. Any project involving dredging, filling, shoreline or streambank stabilization, or other work near or in any lake or waterway requires evaluation by the Corps to determine whether an individual Section 404 Permit will be required, or whether the proposed project falls under an existing permit, called a Nationwide Permit. The latter does not result in public notice of the proposed project. For an individual Section 404 permit, the Corps distributes a public notice of the of the proposed activity to all affected landowners, after which there is a 30 day period for public comment on the project. Plans and descriptions of the project must accompany a Section 404 Permit Application. For Section 404 permit inquiries and requests, information can be obtained from the Louisville District Corps at the following address:

Mrs. Pat Rucker
U.S. Army Corps of Engineers
Operations and Readiness Division
P.O. Box 59
Louisville, Kentucky 40201
(502) 582-5607.

On receipt of a permit application, the Corps notifies the Indiana Department of Environmental Management (IDEM) of the proposed project, and of their action on the permit request. Granting of a Section 404 Permit is dependent on the issuance of an IDEM Water Quality Certification, an authorization to proceed with the project. In most cases, a Water Quality Certification need not be applied for separately, however discussion with IDEM indicates that for a project involving return of water to a lake from an upland sedimentation basin, a Water Quality Certification is necessary despite the fact that the project falls under a Corps of Engineers Nationwide Permit, which does not require an application. A Water Quality Certification can be obtained from IDEM based on a letter describing the project, and granted within a period of two months (John Winters, IDEM; pers. comm.).

For projects on public, natural lakes in Indiana that involve excavating, filling in, or otherwise changing the lake area or depth, a State of Indiana Department of Natural Resources permit is required. This permit application (Form 43008, Permit Application for Construction In or On a Public Freshwater Lake or Lake Michigan), can be obtained by contacting IDNR at the following address:

IDNR Division of Water
2475 Directors Row

Indianapolis, IN 46241
(317) 232-5661.

Plans and a description of the project should accompany the permit application. Discussion with Brian Balsley, IDNR Division of Water, indicates that permit review takes approximately 60 days.

For streambank stabilization work, an individual Section 404 Permit may be required. Excavation and replacement of bank material, as opposed to removal of the material to an upland site, may be grounds for requiring a separate 404 Permit. The Louisville District Corps will need to carefully review the plans for streambank stabilization. An IDNR Construction in a Floodway Permit, obtained from the Division of Water at the above address, will be required for work involving streambank stabilization on Peterson Ditch.

In addition to contacting the State and Federal agencies mentioned above, the WLPA should also contact the Kosciusko County Surveyor, Mr. Richard Kemper, to ensure that he is fully informed of any activity planned or proposed on a regulated drain. Mr. Kemper can be contacted at the following address:

Kosciusko County Surveyor
Room 25, First Floor
Courthouse
100 West Center Street
Warsaw, IN 46580.

9.1 SUMMARY OF PERMIT REQUIREMENTS

The recommended stabilization projects on Peterson Ditch has been discussed with all of the above-named agencies, including the Louisville District Corps. Review by the Corps of the plans that result from the Design Study will be necessary to determine whether a separate Section 404 Permit is necessary, or if a Nationwide Permit will suffice. In addition to the Corps requirements, this project will require a IDNR Construction in a Floodway Permit, also administered by the Division of Water.

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EXHIBITS/ATTACHMENT

Two exhibits are included with this report. Exhibit 1 is a preliminary engineering plan for construction of a containment basin for drying sediments dredged from the mouth of Wyland Ditch. The drawings were based on field reconnaissance of a site on the former Boy's Club Property near the south end of Winona Lake.

Exhibit 2 is a letter from Mr. Michael Armstrong (ETA, Inc.) to Mr. Michael Bonoff (IS&T, Inc.) documenting the evaluation of existing sedimentation basins for use in a proposed Wyland Ditch dredging project.

The Attachment to this report is a copy of "A Model Ordinance for Erosion Control on Sites With Land Disturbing Activities", published by HERPICC (1989).

EXHIBIT 1. **PROPOSED WINONA LAKE DREDGE MATERIAL PLACEMENT SITE ON FORMER BOY'S CLUB PROPERTY**

Engineering Technologies Associates, Inc.
Engineers • Planners • Surveyors

3458 Ellicott Center Drive, Suite 101
Ellicott City, MD 21043

Baltimore Area (301) 461-9920
Washington Area (301) 621-4690
FAX: 750-8565

February 11, 1991

Mr. Mike Bonoff
International Science & Technology, Inc.
10501 Hague Road
Fishers, Indiana 46038

RE: Winona Lake
Dredge Material Placement
Feasibility Study

Dear Mr. Bonoff:

In response to your request, Engineering Technologies Associates, Inc. has determined the feasibility of utilizing an existing dredge material disposal site for placement of material which is proposed to be dredged in Winona Lake at the mouth of Wyland Ditch.

Efforts to find alternative sites which could be either permanently or temporarily utilized for the proposed dredge material placement have not been successful. We have fully evaluated three alternatives for disposal of dredge material: basin construction on the former Boys Club Property, an in-lake disposal option, and utilization of existing basins at the Grace College site in the Town of Winona Lake. An engineering design was developed for basin construction on the Boys Club Property. Five copies of this design are attached. For the in-lake disposal option, our staff developed several drawings which depict dredge material placement in Winona Lake itself.

It is not recommended that the dredge material be transported by trucks directly from the dredge site to an area remote from the site. An operation of this nature would not be advisable and might not be approved by the Town of Winona Lake, due to streets of the town being subjected to deposition of sediment during the transport of saturated dredge material.

The remainder of this letter addresses the feasibility of utilizing the aforementioned existing basins at the Grace College site. The site is located about sixteen hundred feet due north of the mouth of Wyland Ditch. The following Exhibits are attached.

Exhibit 1	-	Vicinity Map
Exhibit 2	-	Existing and Proposed Basins
Exhibit 3	-	Cross Section Through Basins
Exhibit 4	-	Basins With Separation Dikes
Exhibit 5	-	Limit of Proposed Dredging

In regard to the status of the currently ongoing dredging project, on January 24, 1991, I spoke with Mr. Ed Purrington, the Town Coordinator of the Town of Winona Lake. The following summarizes the information given by Mr. Purrington:

1. The existing dredge disposal basin has been built by means of utilizing excavated earth in the dredge material storage area to construct dikes at the basin perimeter. The dikes are estimated to be five feet in height with a two-foot top width and twelve-foot base width. There are no drainage outlet structures in the basin.

2. In the spring of 1990, during approximately six weeks of the dredging operation from Winona Lake Canal, the existing basin was filled to a height of about four feet. Although there was no employment of construction techniques which would be specified under an engineering design for a project of this type, the existing containment dikes are stable at the present time.

3. There is currently no site available for removal of the dredge material in the existing basin. This is due to the composition of the material which has generated certain disposal requirements by the Indiana Department of Environmental Management (IDEM). Mr. Purrington feels that an approved disposal site will ultimately be obtained; the negotiation process is ongoing. However, the time frame for site attainment is unclear. Mr. Purrington expressed his opinion that the earliest possible date for removal of the existing dredge material will be early summer of this year.

4. An area adjacent to the existing basin may be available for construction of an additional basin, per Exhibit 2. The existing basin has been filled to approximate maximum capacity. Since an estimated three thousand (3,000) cubic yards storage volume is needed for the remainder of the Winona Lake Canal dredging, it is possible that the additional basin may be constructed in the near future. It is anticipated that no area beyond that which is shown on Exhibit 2 will be available for dredge material placement.

Based upon the estimated dimensions of the existing basin, the available storage volume in the basin is about three thousand (3,000) cubic yards. This estimate considers one foot of freeboard between the top of the dike and top of dredge material. The proposed basin, if built for the canal dredging, would be constructed in the same manner as the existing basin. Using the dike dimensions of the existing basin, the storage volume in the proposed basin would be about two thousand (2,000) cubic yards. Therefore, the total combined storage of the existing and proposed basins is about five thousand (5,000) cubic yards.

As shown on Exhibit 5, the area of the proposed dredging at the mouth of Wyland Ditch is about four hundred feet by one hundred fifty feet. Including the dredging to be done in Wyland Ditch itself, the total estimated volume of dredge material is approximately fifteen thousand (15,000) cubic yards.

When the Winona Lake Canal dredging project has been completed and the dredge material has been dewatered and removed from the disposal area (see Exhibit 2), the site could possibly be utilized for dredge material placement from the proposed Wyland Ditch project. However, it is not recommended to utilize the existing dikes for dredge material containment. The dikes may not be stable and failure could occur.

According to the data furnished by Mr. Purrington on the attached Exhibits, it is extremely unlikely that it will be possible to create an engineering design which would accomodate the total volume of dredge material from Wyland Ditch. It would, therefore, be necessary to singularly or in combination: decrease the area of the proposed dredging, phase the dredging operation in a manner which would decrease dewatering time for the material, or decrease dewatering time by other proven methods.

The following recommendations should be implemented in order to generate an engineering design for the Wyland Ditch dredge disposal site:

1. A topographic survey of the area should be performed in order to determine the precise limit of the area available for basin construction. Existing elevations need to be established.

2. An outlet structure for the basin(s) would be designed to accelerate dewatering of the dredge material. The engineer would utilize the topographic information in order to create a design which would maximize storage volume within the limit of construction.

3. The dikes for the basin would be designed to meet minimum engineering dimensional and stability requirements.

4. Separation dikes (see Exhibit 4) could be constructed in order to separate and decrease the dewatering time for the dredge material. Dewatering structures for the basins would be designed as required.

5. It is recommended that an approved disposal site for the dewatered dredge material is obtained prior to beginning the dredging operation. This would allow removal of material from the basins during the dredge operations. Therefore, additional volume for dredge material would be created.

Please find the attached five copies of three sheets which depict the engineering design for <u>Little Barbee Dredge Material Placement</u> in Kosuisko County, Indiana. These plans are included with this submittal to indicate the type and extent of engineering necessary to generate plans for the proposed Wyland Ditch dredge operation.

I am very appreciative of your attention regarding this matter. If you have any questions or comments, please call.

Very truly yours,

Michael N. Armstrong

Michael N. Armstrong, P.E.

MNA/cfc

cc: Ed Purrington

STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
INDIANAPOLIS, INDIANA

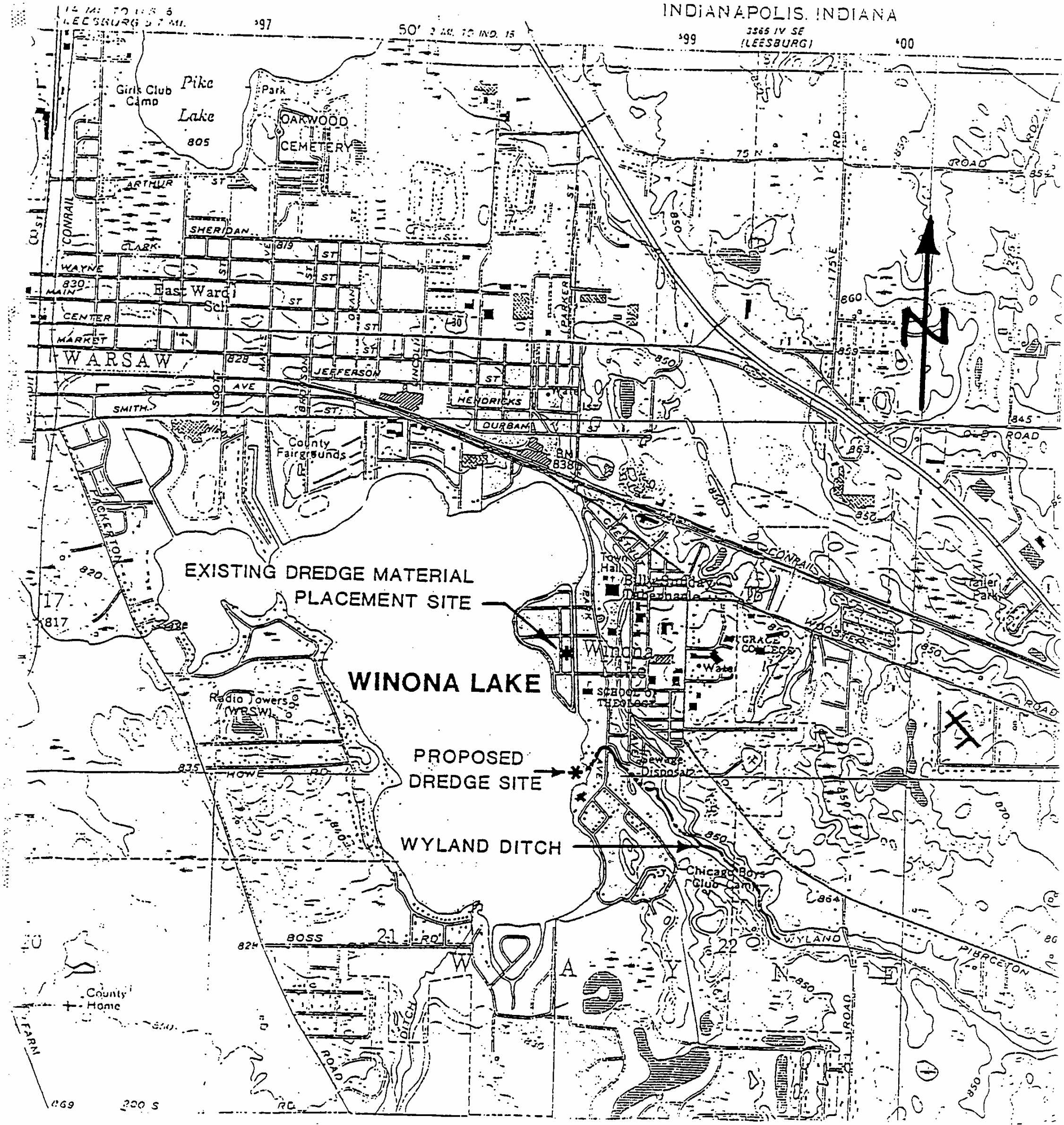
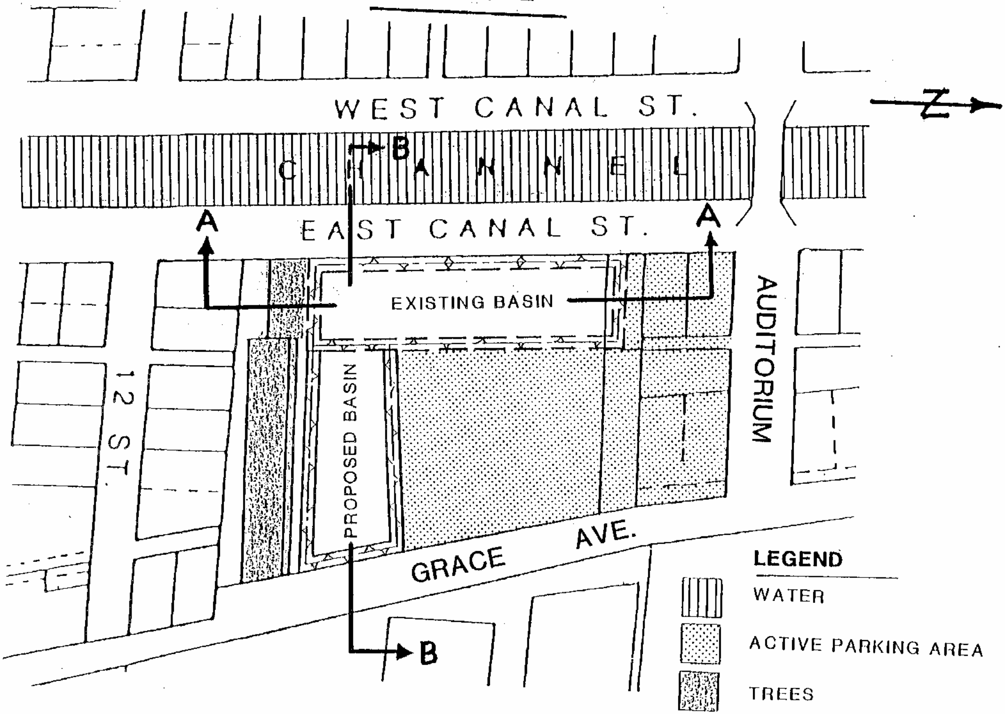


EXHIBIT 1

VICINITY MAP

SCALE : 1" = 2000'

EXHIBIT 2

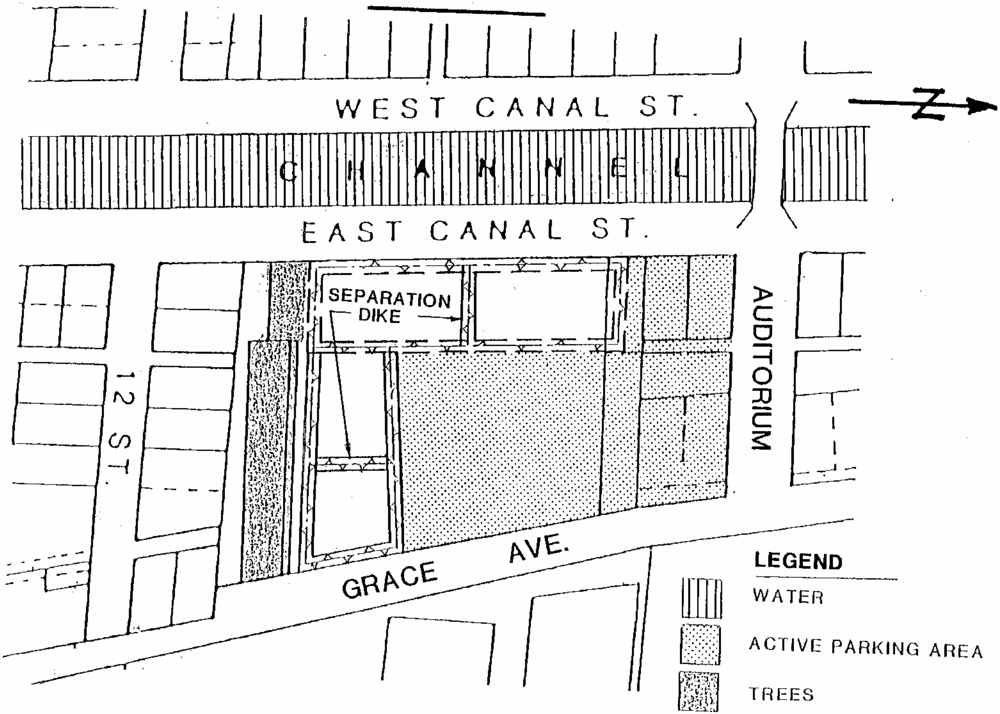


PLAN

SCALE : 1" = 100'

EXISTING AND PROPOSED BASIN

EXHIBIT 3

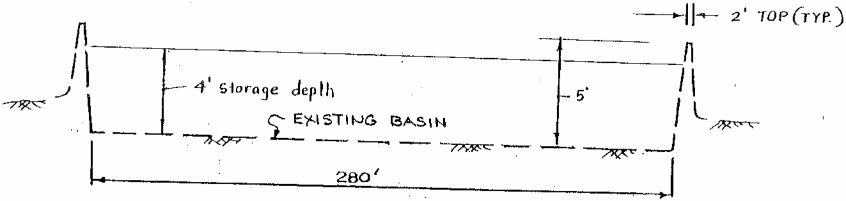


PLAN

SCALE : 1" = 100'

BASINS WITH SEPARATION DIKES

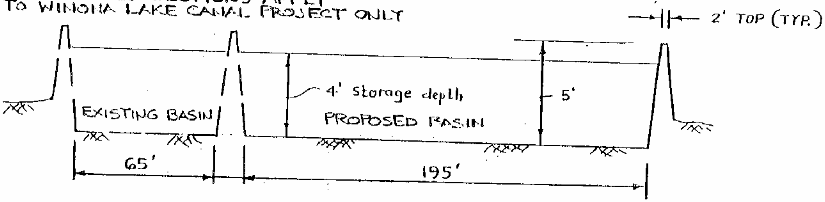
EXHIBIT 4



SECTION – 'A-A'

Scale : 1" = 50' Horz.
1" = 5' Vert.

NOTE : BASIN CROSS SECTIONS APPLY
TO WINONA LAKE CANAL PROJECT ONLY



SECTION – "B-B"

Scale : 1" = 50' Horz.
1" = 5' Vert.

CROSS SECTION THROUGH BASINS

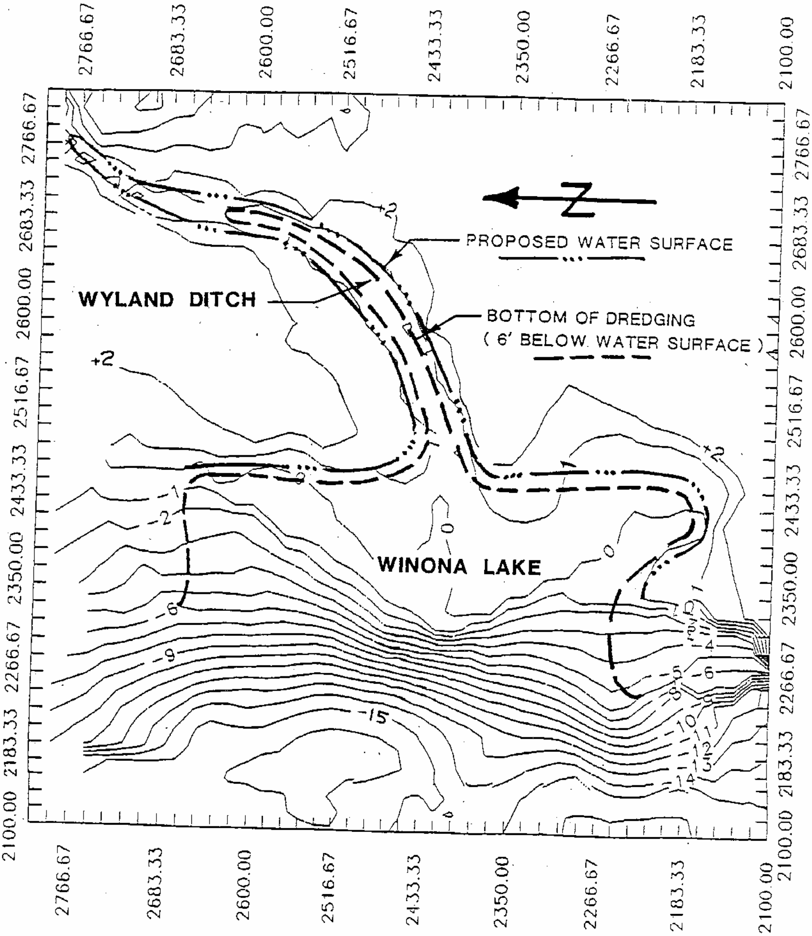


EXHIBIT 5

LIMIT OF PROPOSED DREDGING

SCALE : 1" = 100'